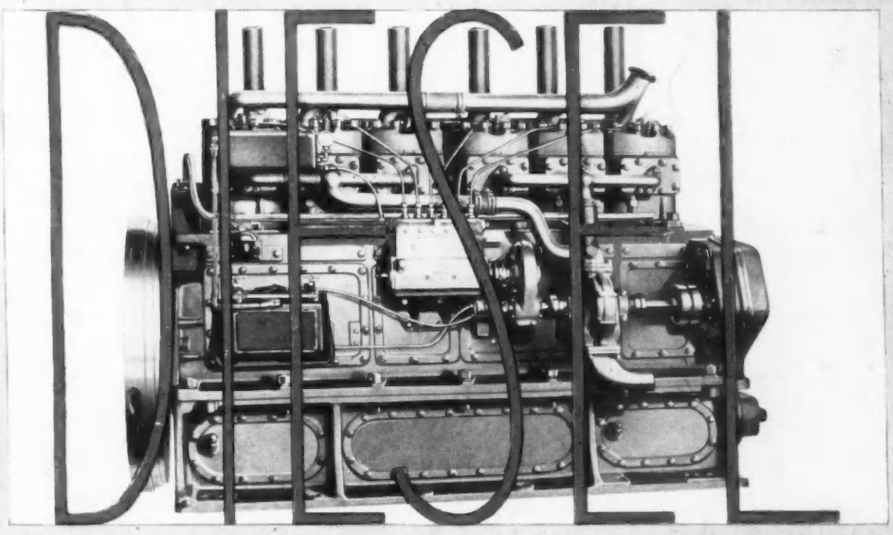
S·A·E JOURNAL



MARCH 1932

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Watson Double Acting Gyro Stabilators have been undergoing road test now for nearly one year, covering temperature and road conditions from Canada to Tennessee, including the states of New Hampshire, Vermont, Massachusetts, Connecticut, New York, New Jersey, Pennsylvania, Maryland, West Virginia, Virginia and North Carolina.

On top of our testing you will, of course, when the time comes, want to do plenty of endurance testing of your own, but we predict that you will find this work to be quite an unusual pleasure.

JOHN WARREN WATSON COMPANY
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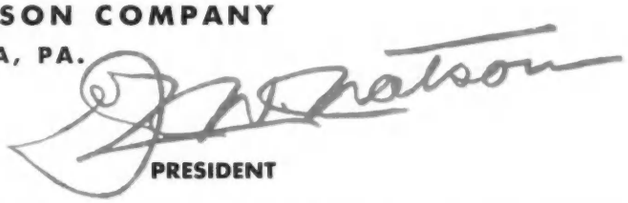

PRESIDENT

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S·A·E· JOURNAL

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NOTE: Page numbers above that are preceded by (T) refer to the TRANSACTIONS section (between pp. 24 and 25 of the advertising and news section) containing papers and discussion that will be embodied in the volume of S.A.E. TRANSACTIONS for 1932, to be issued early in 1933.

The purpose of meetings of the Society is largely to provide a forum for the presentation of straightforward and frank discussion. Discussion of this kind is encouraged. However, owing to the nature of the Society as an organization, it cannot be responsible for statements or opinions advanced in papers or in discussions at its meetings. The Constitution of the Society has long contained a provision to this effect.

ON THE AIRWAYS TODAY
as on the highways for the last 30 years !

"Guaranteed Forgings"

WYMAN-GORDON

Worcester, Mass, and Harvey, Ill.

S·A·E JOURNAL

Splendid Program for Aeronautic Meeting

Society and Aeronautical Chamber of Commerce to Cooperate in Two-Day Sessions in Detroit, April 6 and 7

THE FIRST of the two General Aeronautic Meetings for the year 1932 will again be held in Detroit at the time of the National Aircraft Show. The condensing of all aircraft shows into one National exhibition held annually has provided a concentration of aeronautic engineers and executives each April in connection with this event.

This year the Aeronautic Meeting will again be a cooperative affair with the Aeronautical Chamber of Commerce, which stages the National Aircraft Show, to the extent that the program has been worked out to avoid conflict of Chamber meetings with those of the Society. The Society's Detroit Section has also offered its complete cooperation.

Believing that one of the most advancing phases of aeronautic engineering is that involved in the maintenance of air-transport equipment, it is planned to include, with the cooperation of the Operation and Maintenance Committee of the Aeronautical Chamber of Commerce, a session devoted to the problems of aircraft maintenance engineering so that these may be brought up by airline operating engineers for discussion with manufacturers of aircraft engines and equipment. It is believed that in time this will become one of the most important of the Society's activities in the aeronautic field.

Because of the coordination of this work with that of the Aeronautical Chamber, the two organizations will maintain headquarters at the Hotel Statler and meet jointly therein.

Papers at Technical Sessions

The S.A.E. technical sessions will begin on the morning of April 6 and be followed by sessions in the afternoon and evening of that day and by two technical sessions on the following day. This year's program will contain engineering papers on some of the foremost developments that have been made in the last year.

Harold Gatty, best known for his flight around the world with Wiley Post, who has recently been appointed chief navigation engineer of the Army Air Corps, will present a paper on aerial navigation. Mr. Gatty is regarded as the foremost aerial navigator in the world, and this technical discussion of his methods should be of the utmost interest to the industry.

Aerodynamics and Maintenance Problems

Among other outstanding papers are the Use of Polarized Light for the Study of Strains in Indeterminate Structures, by D. L. Pellett, of the University of Cincinnati; Airplane Load Factors, Logical Determination, by Edward P. Warner, editor of *Aviation;* Research in Autogiro Development, by A. E. Larsen, of Pitcairn Aircraft, Inc.; and Simplified Flight Control Through Air Visualization, by Ralph Upson.

Mr. Larsen's paper on the Autogiro will be of special interest to designers, as for the first time the problems, methods and results obtained in the many research problems arising before successful Autogiros could be produced will be presented for discussion. Similarly, it is expected that, in view of the interest exhibited in the paper presented last August in Cleveland by J. S. Newell, of Massachusetts Institute of Technology, on A Rationalization of Load Factors for Airplanes in Flight, equal interest will be evinced in the paper on this same subject to be presented by Mr. Warner.

At a session on aircraft-maintenance engineering, one of the papers will be by Luther K. Harris, chief engineer of the Ludington Air Lines, who will speak on Maintenance Problems from the Service Viewpoint. It is hoped that, through the activity being initiated in this particular session, air-transport operating engineers and manufacturers can be brought together in a common discussion of the requirements of such operators in the matter of equipment and that the ultimate result will be a perfection of equipment and a reduction of maintenance and overhaul costs.

A second paper dealing with maintenance engineering problems will be presented by the engineer of another airline, setting forth the views and experiences of his line in the field of maintenance.

It is not possible at this time to definitely give all of the engine subjects on which papers will be presented, owing to the difficulty of securing the release of information on some of the latest researches in this field, but outstanding among these will be a paper by Ronald M. Hazen, assistant engineer of American Airplane & Engine Corp., on the problems encountered in the development of high-speed, supercharged, air-cooled aviation engines.

Joint Society and Chamber Banquet

The joint banquet of the Aeronautical Chamber of Commerce and the Society will be held on Thursday evening, April 7, at which time the Wright Brothers' Medal and the Manly Memorial Medal, awarded each year by the Society, will be presented to the authors of the best papers on aerodynamics and engines presented before the Society during the year 1931 as determined by the Boards of Award.

Meetings Calendar

National Meetings

21st National Aeronautic Meeting—April 6 and 7

Hotel Statler, Detroit

In conjunction with the Aeronautical Chamber of Commerce of America

Summer Meeting—June 12 to 17

White Sulphur Springs, W. Va.

March Section Meetings

Baltimore—March 10

Emerson Hotel; Dinner 6:30 P.M.

Speaker, J. F. Winchester, Superintendent of Motor-Vehicles, Standard Oil Co. of New Jersey

Buffalo—No Meeting

Canadian—March 8

Royal York Hotel, Toronto; Dinner 6:30 P.M.

Joint Meeting with Canadian Automobile Chamber of Commerce

Speakers: Alfred Reeves, Vice-President and General Manager, National Automobile Chamber of Commerce; The Hon. W. G. Martin, Minister of Public Welfare

Chicago—March 16

Hotel Sherman, Bal Tabarin; Dinner 6:30 P.M.; Entertainment; Ladies' Night

An electrical demonstration featuring audible light—John Bellamy Taylor

Cleveland—March 14

Cleveland Club; Dinner 6:30 P.M.

How Trucks Meet Present and Projected Road Limitations—R. W. Knowles, Transportation Engineer, The White Co.

Taxation Relief by Revision of Highway Financial and Administrative Policy—Dr. J. Gordon McKay, Director of Cleveland Regional Highway Bureau

Dayton—March 8

Engineers Club; Dinner 6:30 P.M.

Enginering Experiences — Walter T. Fishleigh, Consulting Engineer

Detroit—March 14

Book-Cadillac Hotel; Dinner 6:30 P.M.—Ladies' Night; Dinner meeting and dance

O. T. Kreusser, Director of the Museum of Science and Industry, of Chicago, and former Chairman of the Section, will describe the Museum and his work

Indiana—March 10

Hotel Severin, Indianapolis

Engine Meeting

Kansas City—March 29

Metropolitan—March 24

A.W.A. Clubhouse, 357 West 57th Street, New York City; Dinner 6:30 P.M.

The Car of the Future—Sir Dennistoun Burney

Milwaukee—March 2

Milwaukee Athletic Club; Dinner 6:30 P.M.

Engine Cooling—Louis Schwitzer, President and Chief Engineer, Schwitzer-Cummins Co.

New England—March 16

Hotel Kenmore, Boston; Dinner 6:30 P.M.

Automoble Transmissions

Northern California—March 14

San Francisco

Transportation Meeting

Northwest—March 8 and 10

Vancouver, B. C., Meeting, March 8, Medical and Dental Building; 8 P.M.

Professor Gillies, of University of British Columbia, will speak

Seattle Meeting, March 10, New Washington Hotel; Dinner 6:30 P.M.; Entertainment

Trend of Current Research in Field of Automotive Powerplants—Prof. F. G. Baender, Oregon State College

Oregon—March 11

Multnomah Hotel, Portland; Dinner 6:30 P.M.

Truck and Highway Legislation—H. W. Roberts, Secretary, Roberts Motor Co.

Commercial-Vehicle Requirements as Viewed by the Public—Ray Conway, Manager, Public Relations Department, Oregon State Motor Association

Highway Transportation Engineering Requirements, Regulation and Taxation—A. J. Scaife, Consulting Field Engineer, White Motor Co., and President of the S.A.E.

Pittsburgh—March 1

Fort Pitt Hotel; Dinner 6:30 P.M.

Mufflers, Air-Cleaners and Carbureter-Air Silencers—William Jack, Chief Engineer, Acoustical Division, Burgess Battery Co.

St. Louis—March 8

Engineers Club; Meeting 8:00 P.M.

State Highways—the Automobile's Relation to Mileage, Building and Motorists' Rights.

Southern California—March 18

Elks Club, Los Angeles; Dinner 6:30 P.M.

Watt Moreland, President and General Manager, Moreland Motor Truck Co., and several other prominent automotive men will speak

Syracuse—March 8

Hotel Syracuse

Startex Drive—M. P. Ferguson, Sales and Service Engineer, Eclipse Machine Co.

Die Castings, Their Production and Application—W. J. During, Chief Engineer, Precision Die Castings Co.

Wichita—March 28

Green Parrot Inn; Dinner 6:30 P.M.

Application of Air Wheels—Larry Gunther, Goodyear Tire & Rubber Co.

Society's Activities Impress a Distinguished British Engineer

How the functioning of the Society appeals to a British visitor of many accomplishments is revealed in the accompanying letter from Sir Dennistoun Burney. The letter is of particular interest also for the author's observations on American roads and driving conditions and the combination of car qualities necessary for both town driving and long-distance touring.

The paper on the Development of a Rear-Engined Streamline Car, which Commander Burney presented at the Annual Meeting, attracted one of the largest audiences that ever attended an S. A. E. technical session.

Sir Dennistoun Burney, son of Admiral Sir Cecil Burney, succeeded to the baronetcy in 1929. During the World War he invented the Paravane, a device attached to ships for sweeping mines from the sea. He was elected a Member of Parliament from Uxbridge in 1922, was managing director in charge of design of the British airship R-100, and is a retired officer of the British Navy. For many years he has studied aircraft design and of late has applied his knowledge of dynamics and streamlining to the designing of a dynamically correct and aerodynamically efficient automobile.

The Baronet's Appreciation of the Society

Dear Mr. Warner:

May I say I feel much honored in being allowed to enjoy the benefits of a Society such as yours? In the short time that I have been over here, I have been much impressed not only with the most useful work that the Society is doing in the interests of the automobile industry, but what has struck me most forcibly has been the willingness of the various members to exchange the results of their own investigations and experiences.

Another matter, which I shall endeavor to initiate in England, is a move toward a better official standardization of manufacturing details and facilities. I find on enquiry that it was largely due to your Society that the automotive industry enjoys a very practical official standardization of parts and materials, and in my humble opinion this standardization is a condition precedent to the development of any industry on mass-production lines.

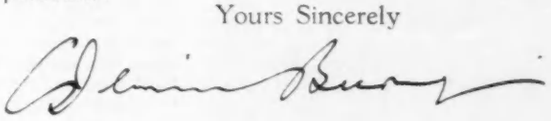
I should like to add how gratified I have been at the reception of my ideas. Sometimes an outsider is somewhat resented when he ventures to criticize the established practice of a developed industry. I found, however, not only were my proposals considered on their merits, but that the only suggestions made were those directed to helping me to forward the proposals and develop the ideas. Having spent some twenty years trying to invent various devices, it was like receiving a stimulating draught of a refreshing beverage.

On my first long run on American roads I was impressed at the high average speed possible and at the absence of what I believe are called "speed cops," as during the second day's run we averaged 57 m.p.h., running time. It seems to me that, with the continued development of your magnificent highways, cruising speeds are bound to rise and that in consequence the question of wind resistance will become of increasing importance.

One other feature that has impressed me is the very different requirements for the car used in the towns, with their congestion and light control systems, and that required for long-distance touring. I imagine that the problem of the future is to combine the necessary qualities for both sets of conditions into one vehicle, as it would be a poor engineering answer to say that one must have two different cars. Personally, I expect to see the cars get slightly longer to give the necessary space for comfort and to assist in obtaining a good aerodynamic shape.

In conclusion, may I express my most sincere thanks to you and your Society for the trouble you have taken to make my path easy and my stay pleasant?

Yours Sincerely



Get Your Man!

Promising Results Already Indicate a Successful Membership Campaign

THE SHORT MONTH that has elapsed since the inauguration of the Get-Your-Man compaign has clearly demonstrated the whole-hearted interest which individual members and the Sections have taken in this opportunity to bring advantages of membership in the Society to the attention of men throughout the industry.

It has been demonstrated beyond doubt that there are vast numbers of men who are waiting to be informed on the subject of the Society; men who are anxious to join and participate in its activities; and many others who, while generally cognizant of the Society's influence and benefits, are merely waiting to be asked.

The number of signed applications received daily and the quantity of returned postal cards, indicating distribution of application blanks, coming into the New York City office pressage fair sailing ahead.

The results thus far obtained are due largely to the efforts of individual members of the Society, as the majority of the Sections are still perfecting the organizations through which they hope to place themselves in the first rank when awards are made. Available information indicates that a perfect machine is functioning in the Baltimore Section in the nature of an Accelerating Committee of more than 20 members, one from each of the various branches of the industry and fields of endeavor, together with a few representatives of particularly large business organizations. Detroit is similarly organized. The New England Section is actively making an analysis of the entire Section territory to determine its eligible prospects. The Metropolitan Section is waging a contest within a contest for members of the Section. While details of the plans of other Sections have not been received, the applications coming through have indicated that feverish activity must be taking place in many quarters. Well up in the front of this group is the Indiana Section.

Two Sections Declare War

A friendly membership war has been declared between the Metropolitan and Detroit Sections. A recent number of the *Metropolitan Section Booster* challenges:

"Get Your Man—Beat Detroit! In Detroit this month 'K' Glynn challenged Detroit Section, promised 'em a spanking, reminded 'em of the previous licking and made 'em like it!"

From the February *Detroit Supercharger* issues forth: "The 'Get-Your-Man' campaign is on its way, and with it has come a challenge from the Metropolitan Section. The actual wording of the challenge was 'We'll lick the pants off Detroit.' The Detroit Section will undoubtedly attend to this matter with the usual Detroit dispatch."

In the meantime, it has been definitely determined that some of the other Sections are preparing to come out 'way ahead of both these Sections when the final count is made, thereby indicating the superiority of peace over war.

Metropolitan Section Contest

One of the novel methods being employed to stimulate the securing of applications is the Metropolitan Section application contest. A donated prize has been secured for each monthly meeting of the Section, this prize to be awarded to the member of the Section who turns in the largest number of applications since the preceding meeting. While the Get-Your-Man contest awards are made by the Society on the basis of members elected and qualified, the Metropolitan Section has, for the purpose of stimulating activity, based this contest solely on applications secured.

The fact that the closing time of each month's contest is the time at which the technical meeting starts provides an opportunity for members to secure applications from those attending the Section dinner and adds a considerable element of chance.

Why not try this in your Section?

A significant indication of the interest of members is found in the fact that, although one application blank had been placed at each place at the dinner table, not one was left behind at the close of the meeting.

Pick Your Man Before Getting Him

Since qualifications for membership are to be maintained at the usual high professional standards, it is urged that Society workers avoid embarrassment by picking their men very carefully before inviting them to apply for membership. Our Council has directed that the usual careful study of qualifications and references be made by the Grading Committee in all cases. Most decidedly there is to be no letting down of the bars to persons who are not fully qualified to join our ranks.

Dues Exempt from Taxation

Attention is directed to the fact that money paid to the S.A.E. for initiation fees and dues is deductible from income-tax statements. At least, this applies to the Federal tax and some of the State taxes.

The Awards

Although awards of great monetary value will come to those who succeed in getting their men, the rewards of even greater significance will rest in the realization of services well performed for the individual benefit of new members and for the collective advantage of the Society as a whole. WATCH THE JOURNAL EACH MONTH FOR GET-YOUR-MAN NEWS AND INFORMATION.

PERSONAL CONTACTS OF GREATEST ADVANTAGE

I believe that the greatest advantage the Society has to offer is that of personal contacts with the other fellow in the industry; knowing him personally, being able to sit down with him in a corner, across the table in his office, over a luncheon or dinner, and discuss with him problems that you could not solve in any other way than through this acquaintanceship that you have unconsciously made through affiliation with your Society.

A. J. SCAIFE,
President

Read What Those Who Know Say About Membership Value

On the facing page are printed statements made at Sessions of the Annual Meeting by several prominent members of the Society regarding the value to be derived from membership and how to Get Your Man. They spoke from personal knowledge gained from their attendance at meetings and participation in the activities of the Society. Their testimony that a member gets back more direct value than he puts in, and can get indirect returns in proportion to his contribution of interest and effort, is convincing.

Prominent Members Tell You How

Thrills of an S.A.E. Meeting

FOR ME TO SAY a word about the advantages of membership in the S.A.E., principally to those who are not now members, is almost like talking on why it is good to be living and having a lot of fun. The worth of membership and association in the Society is so outstandingly apparent to me that I am likely to oversell the idea.

First, there is the association in meetings like this; the feeling that we are a part of a discussion which perhaps tonight has led the automotive world, not only in this Country but throughout the world; second, to be a part of an audience like this, the largest I have ever seen in any S.A.E. meeting under any conditions; third, the opportunity to be here and meet dozens of old friends and associates, all of whom you are very glad to see and yet whom you see perhaps only at the S.A.E. meetings.

Just look around, and if any of you who are members haven't had that experience and this thrill we all get with our old friends, there is something wrong with what you are putting into the S.A.E.

W. T. FISHLEIGH

Participation in Activities Is of Greatest Worth

ONE idea that impresses me particularly is that we have got to be realists in this situation; one thing that a fellow can get out of the Society by being a member that he can't get out of it without being a member is the possibility of participation in its activities. The activities of this Society are both technical and non-technical. The technical man who comes into the Society with the idea of participating in its activities has an opportunity, not only to meet people and to gather ideas, but to get the feel of what is going on in this tremendous industry.

Here is an industry which does two or three billion dollars' worth of business a year. It is widespread all over the United States. It is traveling fast, from the engineering standpoint, the production standpoint and the maintenance standpoint. The things going on in this industry are tremendous.

By joining the Society, a man has an opportunity to participate with other men and minds, and so gets a personal feeling through sitting in meetings with his ears open, that can come out in his daily work in a way that never can come out through reading the S.A.E. JOURNAL.

I believe that the thing we have not sold in this Society is the information, the contact and the personal development that is possible through participation in its multitudinous activities. Naturally, this Get-Your-Man luncheon gathering is a group of men who have been active in the Society; the places where you have got the real value out of your membership are, for the most part, the committee groups in which you have taken part in something that was being done.

That isn't an opportunity that is open to only a chosen few. There are plenty of committees in this Society and plenty of work to be done; there always will be, and the more men we can make active, the better it is going to be for the Society. Only in that way, as I see it, can a man get the greatest value out of his membership.

I feel that the intangibles, which are so hard to explain, are very definitely the most important things you can get out of a membership, and are something a man can't get if he is not a member.

NORMAN G. SHIDLE

Aggressive Effort Brings Success

TO KEEP the strength of the Society where it should be, we must pursue this Get-Your-Man campaign 100 per cent.

The difference in membership activities, in the various sessions and throughout the Society, between passive effort and aggressive effort is just the difference between success at this time and failure. For example, I have known of four or five men around New York City who should be members, and have talked with them about it from time to time, but hadn't flashed an application blank on them. When I did, just before coming to the Annual Meeting, I found those men were willing to become members, and they promised to do so. It was just the difference between passive effort and aggressive selling.

Let us, for the next six months, make an absolutely aggressive campaign. Let us look over our friends in the automotive industry and judge them as to whether or not they are good caliber for the S.A.E. We want engineers, executives and other men who, while possibly not technically trained, are so intimately woven into the structure of the industry that they belong in the Society.

If you do not own an S.A.E. pin, buy one. Wear it. Talk S.A.E. Point out how it benefits its members. Carry Get-Your-Man application blanks in your pocket at all times. And when you lead your man up to the thought of joining, sign him up on the spot. If you can't do that, follow him, always with this application blank ready.

Help the applicant with his references. Sometimes it is rather hard for an applicant to remember five or six references, as required. If he is a friend, you probably know some of his friends who are in the Society and who can aid the Grading Committee in placing the man in the right member grade.

Impress upon your prospects the need for correct information. Nothing in the Constitution or By-Laws of the Society prevents a man who lacks a technical degree from becoming a full Member. Impress that point upon him so that the application will contain the fullest and most correct information for the guidance of the Grading Committee.

The prizes offered in this campaign are a distinct honor, but the biggest and best prize is the advancement of the S.A.E. in the world's affairs.

F. K. GLYNN

Pays 71-Per-Cent Dividend

IN THESE DAYS of dividends and deficits, I can't think of any better way to show you what is on the board in graphic form, reverting to the old Chinese proverb that one seeing is worth 1000 tellings. The average direct return or dividend based upon S.A.E. dues is 71-per-cent. Figuring direct and indirect returns, the actual dividend amounts to 196-per-cent. You can look over the Big Board, the Little Board, the Curb, and a lot of the rest of them, and there are very few investments paying anything like a 71-per-cent dividend today.

Some friends of mine in New York City have been looking over all the societies to which they belong and dropping out of those from which they are not getting as much in return as they feel they are entitled to. I don't know of a single association that can actually show me in dollars and cents the returns I get from it as the S.A.E. can.

I should say that the gist of the whole story is to pick your prospect. We want only qualified men. Don't use a garden hose and spray it all over the lot. Pick out marked game and shoot through a high-powered rifle with armor-piercing ammunition.

When you make contact with a prospective member, remember that, if you have picked him out carefully and have faith in your product and he has faith in you, he probably will say, "Well, if you say it is all right, I will go into it."

MAURICE HOLLAND

Chronicle and Comment

Society's Biggest Meeting

INDICATIVE of increasing interest in S.A.E. affairs, the Annual Meeting this year was the *best attended of any technical meeting in the Society's history.* With a total registration of 1347, past records were exceeded by more than 100. It is interesting to observe that only 37 registered members were without a company connection. Audiences at two of the sessions exceeded 1000 each.

It is perhaps unnecessary to remark that the quality of the technical papers fully measured up to the usual high standards of excellence.

Of course, the gage of a meeting's success is not entirely a matter of numbers. Nevertheless, it is reasonable to assume that, other things being equal, record-breaking attendance is indicative of an increasing interest among members; which in turn must depend largely upon the attractiveness of the program that our officers and committeemen have been able to prepare.

Motorboaters Learn About Marinas

UNDER the able sponsorship of the Metropolitan Section, a large gathering of motorboat enthusiasts and marine engineers enjoyed a lively semi-technical meeting in New York City on Feb. 18. W. E. John, who was largely responsible for the generous and interesting program, introduced a half dozen speakers who covered a broad array of subjects including the story of motorboat progress from naphtha launches to present developments, the promotion of boating "highways" and marinas or standardized parking facilities, the production of boats in quantity, the possibilities of fire prevention and the advantages of hydrogenated fuels from the non-inflammability standpoint.

An account of the meeting will be found on p. 27 of this issue of THE JOURNAL.

Aeronautics Next Month

VICE-PRESIDENTS Lawrance and Stout, together with Dr. G. W. Lewis, chairman of the Activity Meetings Committee, and his associates are responsible for an excellent program of technical sessions and banquet for the Aeronautic Meeting in Detroit next month.

This important affair will be held again in cooperation with the Aeronautical Chamber of Commerce of America, with the Hotel Statler serving as headquarters for both organizations. The official Aircraft Show will run concurrently with the S.A.E. meeting and will offer another strong attraction to aeronautical engineers.

The Detroit Section has also offered its full cooperation in the meeting.

Membership Is Increasing

NO SOONER had the opening gun been fired than the results of the Get-Your-Man campaign began to appear. At this time, a goodly number of promising applicants have made their appearance and are receiving the usual careful consideration of the Grading Committee.

Not all who are called will be chosen, for the professional standards of the Society are high. However, the "pick-your-man" attitude, combined with the "get-your-man" spirit, is bound to bring results of great benefit to the Society and its members.

Each issue of the S.A.E. JOURNAL will carry a timely report of the Get-Your-Man enterprise.

Wear Your Badge!

CERTAINLY the Society's official symbol is a mark of distinction —*the Hallmark of Automotive Engineering.* Whether an individual member wears the official pin or not may seem to matter little; but a great many of our engineers would feel improperly dressed without it. Our Council recently suggested that the wear-your-badge idea be encouraged. Page xxviii of the new Roster displays the pins and charms and shows how little they cost.

Thoughts of Our Leaders

MESSAGES of intense interest often come to the Society from prominent automotive men whose ideas and judgment carry great weight in the industrial world. From time to time these important communications have found a place in THE JOURNAL. In the January issue, Past-President Bendix was heard from; in the February issue, President Scaife extended his friendly greetings; in the present issue, Sir Dennistoun Burney offers his interesting observations in characteristic fashion.

It is suggested that following numbers be watched for these features. Kettering is scheduled for April!

Personality in The Journal

EIGHT HUNDRED and seventy-one persons "appeared" in the February issue of the S.A.E. JOURNAL. Many were contributors of technical papers and discussion; others were participating in the Society's activities or assuming new duties as officers and committeemen; *all* were mentioned because of their useful connection with automotive enterprise.

Our Society gains its vigor and strength from these men and their associates. Our industries are properly proud and appreciative of their progressive spirit of leadership in the engineering profession. The world is better for their effort.

People are interested in people, because personality is at the root of all human endeavor. In recording human endeavor, our JOURNAL reflects the personality of those who *do* things. Thus are our members responsible for its preeminence.

New Roster Lists Over 7000 Members

DURING FEBRUARY the 1932 Roster was mailed to each member in good standing who requested a copy. More than 7000 members are listed in it; this is 2.6 per cent less than the comparable listing in the 1931 Roster. Many consider the Roster to be one of the most useful books in the automotive fraternity. Judging from the large number of engineers who asked for the publication, it enjoys a very wide use.

Controllable and Automatic Aircraft Propellers

20th National Aeronautic Meeting Paper

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THE DEMAND for a successful controllable or automatic propeller is greater today than ever. Such a propeller will enable commercial aircraft to take off safely with greater loads, and it may enable multi-engine airplanes that cannot now maintain altitude with one engine dead to do so with a safe margin of power. For military aircraft it means increased rate of climb and increased speed at altitude, especially with supercharged engines.

To obviate confusion in nomenclature, the authors give definitions of adjustable, controllable and automatic propellers.

Distinction is drawn between the needs of different classes of airplane for different types of changeable-pitch propellers.

Many propellers falling within the several classes have been designed but few are in use. Cost, weight and complication are obstacles to their commercial success.

Several problems still confront the designer in this field, the chief one being that of obtaining material that is sufficiently light and strong. A number of designs have been worked into full-size propellers.

That interest in this type of equipment is far from dormant is evident from the fact that the Army Air Corps is now following the development of eight distinct types. The authors illustrate and describe a number of such propellers that have been tested by the Materiel Division, one of which was evolved by the Engineering Division and is used by the Air Corps.

A NUMBER of articles have appeared from time to time extolling the merits of "controllable," "adjustable" and "variable"-pitch propellers. The logic and quality of evidence presented have left little doubt as to the desirability of such a device, but visits to airports throughout this Country and abroad reveal very few such propellers. After a little thought, one or more methods of pitch control may present themselves to mind, and the originator is likely to conclude, in his enthusiasm, that the solution is simple and that a good opportunity has been overlooked.

While the several published technical and semi-technical articles have been on the theory of the controllable and automatic propeller, only very meager information has been available as to recent progress made in development of this equipment. This lack of information may be laid to the fact that, without exception, all controllable and automatic propellers are still in the experimental stage, and most of those working on this development are hesitant to publish details of a device that is unproved and on which their patent rights may not be fully protected.

The purpose is not to present in this paper the advantages of controllable propellers nor to attempt to establish the relative merits of the various types, but to present an outline picture of some of the things done and being attempted along this line. Much more is being done than is available for publication. Plenty of examples can be presented to show that much more has been done toward the development of controllable propellers than one is led to believe by a round of visits to the airports of the Country.

Adjustable, Controllable and Automatic Propellers

The terms, "adjustable," "variable," "controllable" and the like have been used rather loosely and interchangeably, hence it is advantageous to assign specific meanings to the terminology. The following definitions have been selected for particular reasons. All terms refer to pitch (blade-angle) adjustment or control, the advent of propellers of controllable size (width or diameter) seeming too remote for present consideration.

Adjustable Propeller.—A propeller the pitch of which cannot be changed during flight but which, when the engine is not running, can be adjusted, either on or off the engine. Virtually all of the detachable-blade propellers in general use in America fall in this class. With a wrench and a suitable protractor, the pitch of the blades can be "adjusted" when the propeller is not in operation.

Controllable Propeller.—A propeller the pitch of which can be changed during flight by intentional manipulation by the operator each time a change of pitch is effected, the extent of change being either predetermined or continuously controlled by the operator. The power effecting the change of pitch may be derived from the operator, the engine or some other source, the operator merely determining the time and extent of the change and manipulating the control mechanism.

Automatic Propeller.—A propeller the pitch of which is changed while in flight as a result of a change of conditions, the propeller-controlling and operating mechanisms being constructed to function in response to the change without attention or manipulation on the part of the operator in regard to the time or extent of the change. If the range or extremes of operation are susceptible to adjustment by the operator while in flight or by a mechanic when the engine is not running, that does not affect the classification of the propeller.

The term "variable" is left to represent that characteristic which is more or less common to all propellers; namely, the variation of pitch as a result of distortion of the blades when under stress.

Different Types Applicable to Different Services

To attempt to set up the requirements of an "ideal" changeable-pitch propeller is like trying to define the ideal motor-vehicle. Different classes of service require or permit different types of propeller. The advantages of controllable propellers on certain classes of sport and training airplanes are not so pronounced as on other

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classes of airplanes. This is not because an improvement in performance under certain conditions cannot be demonstrated, but because this gain may not be worth the extra cost in money, weight and the complication of both mechanism and manipulation.

Cargo airplanes generally are limited to loads with which they can take off and climb, and not to loads which they are able satisfactorily to carry once they are in the air. Therefore a controllable propeller of only two blade positions, namely, take-off pitch and normal pitch, should increase the returns by increasing the possible payload. Were the propeller provided with a cruising-pitch position, further economy could be effected in the use of fuel. This, however, should not be secured at the sacrifice of high-speed (normal) pitch, as all airplanes may at some time seriously need a high-speed pitch-setting. Hence a three-position propeller is quite acceptable for this class of airplane and more to be desired than one of two positions. Whether a two-position or a three-position propeller is used, the pitch need not be changed while the propeller is rotating at high speed. For take-off, the angles can be reduced while the engine is idling on the ground. For cruising and high-speed adjustments, the airplane can be glided with greatly reduced throttle while the angles are being changed. Such compromise in the operation of the propeller permits more latitude in its design. The operating mechanism may be lightened and even plain bearings might be used in place of frictionless bearings.

The case of a pursuit or combat airplane is entirely different. The demands of a combat plane on a changeable-pitch propeller include all conditions from steep climbs to vertical dives, with maximum performance available under all conditions. The pilot of a single-seat combat airplane is a busy man during an engagement; keeping his eyes on an adversary, operating airplane and engine controls, and firing machine-guns so completely occupy his time that none can be devoted to his propeller. At the end of a steep dive, during which dive a high-pitch angle was necessary to limit the rotational speed of the engine, a reduced pitch is needed immediately for the climb that follows. An automatic propeller is needed for this type of airplane; a propeller that corrects its pitch to suit changing conditions, and accomplishes this change with very little lag behind the advent of a new condition. The value of such a propeller is further enhanced if its governor or control mechanism is capable of such adjustment while in flight that the pilot can select the range of operation or the condition of response which he desires.

All of the propellers falling within the scope of this article may be classed somewhere between these two extremes; one extreme being the strictly limited controllable propeller, and the other the fully automatic, with governor adjustment while in flight. The extent of the fields of application of the various types is not yet known, hence it is useless to attempt to classify them.

Various Methods of Changing Blade Angle

The force required to change the blade angle on controllable and automatic propellers may be produced and applied in numerous ways. A few fundamental methods are by

(1) Mechanical control, the force being produced by the pilot
(2) Electrical control, the force being produced by an electric motor
(3) Engine control through some type of servo mechanism
(4) Propeller thrust or torque
(5) Centrifugal force on propeller blades
(6) Centrifugal force on counterweights
(7) Hydraulic or pneumatic control.

These are by no means all the possible methods, but they are fairly representative of present attempts. Considerable flexibility as to methods of actuating the blades is available, since in some designs it is possible to combine two or more of these fundamental methods.

There is much to support the belief that the governing mechanism of an automatic propeller should be entirely separate from the actuating mechanism; that the actuating mechanism should have a reserve of force from which to draw that substantially exceeds all opposition encountered from blade forces, springs and friction; and that the governing mechanism should be entirely unaffected by forces necessary to effect changes of pitch and should be designed to accurately discriminate changes to which the propeller should respond.

Some Difficult Problems Confronting the Designer

The introduction of controllable and automatic features into the field of propeller design adds many difficult problems which have not readily been solved by drawing upon experience gained in other fields of engineering. Some typical problems are:

(1) Design of, material for and fabrication of an antifriction bearing which is light, comparatively small, and at the same time sufficiently strong to withstand both the tremendous centrifugal force generated by the rotating blades and the shock loads due to torque variation in the engine. The centrifugal load generated by modern metal propeller blades while the airplane is in flight at cruising speed is of the order of 50,000 lb. and may reach 200,000 lb. on a pursuit airplane in a dive.
(2) A control device which is light in weight and positive in action, the parts rotating with the hub being so disposed that the balance about the axis of rotation of the propeller is preserved
(3) For those actuating mechanisms which require a running connection between cockpit controls and the propeller, a connection which is light, rugged and durable
(4) Modification of the engine.

The fact is significant that, although the problems of the controllable and the automatic propeller have been attacked over a period of about 13 years by many engineers and inventors, no entirely satisfactory propeller of either type has been produced. A few propellers of these types have been flown for comparatively short periods but have not had sufficient use to prove their worth. Many who are working on this problem have unknowingly duplicated the efforts of earlier workers in this field, and in many cases the efforts have been directed by an incorrect conception of the speeds and forces that have to be dealt with.

It is believed that those who contemplate executing some ideas they may have on how to make a controllable propeller would spend time and money to advantage in having a search of patent records made before proceeding with the construction. One fact of which the reader may be assured is that no shortage exists in ideas as to how the pitch of a propeller may be changed in flight. Lack of a method is not keeping controllable propellers from the flyers; the greatest obstacle seems to be the lack of materials light and strong enough to enable the designer to get the propeller within the weight and space limitations established to date. Engines that have required years to develop cannot readily be changed to any great extent. In the past the flying fraternity has been reluctant to accept the added weight and the enormously greater cost associated with the controllable propeller. Together with the prospective advent of new materials which either are lighter and stronger or permit new methods of construction, comes a greater need for controllable propellers than was felt

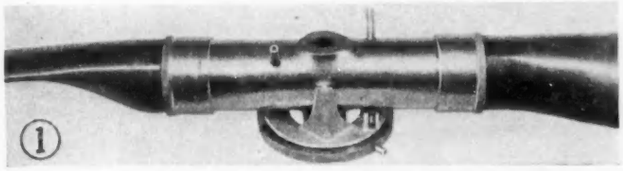

FIG. 1—HART-EUSTIS CONTROLLABLE PROPELLER

Wood Blades Were Pivoted on Antifriction Bearings in the Hub Barrel and Actuated by Means of Pins Connected to Rotating Yokes Controlled by a Non-Rotating Sleeve Actuated by a Lever

in the past. This need may suffice to prevail upon operators to suffer the increased weight of the lighter controllables, but the designer cannot consider that this in any way mitigates the challenge for greater lightness.

Some Types Tested by the Air Corps

The Materiel Division of the Air Corps is now following the development of eight distinct kinds of controllable and automatic propellers, including one of its own design. In the effort to secure a satisfactory propeller of one or other of these types, the Air Corps is aiding in the development by conducting tests on those which show promise of being of use in the military service. This testing is a major item, the costs generally running into thousands of dollars during the development of a single type.

The following are presented as a few examples of what has been done. Only those propellers with which the Materiel Division has had some actual experience in design, construction or testing are mentioned. The order of mention has no bearing whatever upon their relative merits. Models of impractical size and all proposals in only the paper stage that have been submitted are omitted from mention. Therefore this summary by no means exhausts the possibilities in controllable propellers.

Manually Operated Controllable Propellers

The first controllable propeller in which the Army took a definite interest was that made by Seth Hart and Robert I. Eustis, and illustrated in Fig. 1. The essential features of this propeller were as follows: Wood blades were inserted in steel ferrules held in the hub barrel by frictionless bearings so that the blades were free to rotate; to effect rotation of the blades, pins engaging the bases of the blades extended through the barrel and were connected to the rotating yoke of the intermediate control-unit, which could be moved back and forth axially. A running ball race connected the rotating yoke to a stationary yoke attached to an actuating lever, and the connection from that to the cockpit could be made with either rods or cables.

Years of experimentation on the retention of wood blades in the ferrules, on overcoming the large resistance to operation, in counterbalancing centrifugal moments and in the substitution of micarta and aluminum-alloy blades for wood blades resulted in the evolution of the controllable propeller at present in use to a limited extent in the Air Corps. The installation of this propeller is shown in Fig. 2. Its essential features are as follows: Aluminum-alloy blades having hollow shanks and internal bearings; steel sub-extensions from the central portion of the hub to the interior of the hollow blade-shanks to retain the blades through frictionless bearings; centrifugal counterweights to reduce the load on the intermediate-control-unit bearing; screw-actuated intermediate control-unit to give the operator favorable mechanical advantage; intermediate-control-unit lock to relieve cables and cockpit controls of all loads except at the time the pitch is being changed; cable connections between intermediate control-unit and cockpit controls; and pitch indicator in the cockpit. The numerous minor improvements are not mentioned. This propeller has given satisfactory service on Liberty-engined observation-type airplanes, but, as the actual flying time with a single propeller is only a little over 200 hr., the question of life or endurance is still uncertain.

The Engineering Division collaborated with the Standard Steel Propeller Co. in the design of the 400-hp. hollow-steel reversible propeller shown in Fig. 3, which this company manufactured and delivered in 1920. The general scheme of changing the pitch was closely allied to that employed by the Air Corps in its other efforts, but advantage was taken of the hollow blades to encase therein all of the bearings, to utilize hub stubs instead of hub barrels for the support of the blades, and to eliminate ferrules that had to be employed with wood and micarta blades. Duplicate propellers were made with hollow aluminum blades in an effort to reduce the weight incurred in the steel propeller. These propellers were made before centrifugal counterweights were employed, and although the blades turned very freely when the propeller was turning slowly, it was extremely difficult to increase the pitch when running at the higher speeds; in fact, a great deal of force was necessary just to hold the blades at normal pitch-setting and to keep them from turning to a low-pitch angle. This imposed a heavy continuous load on the intermediate running bearing. With its deficient lubrication this was found to be unsatisfactory.

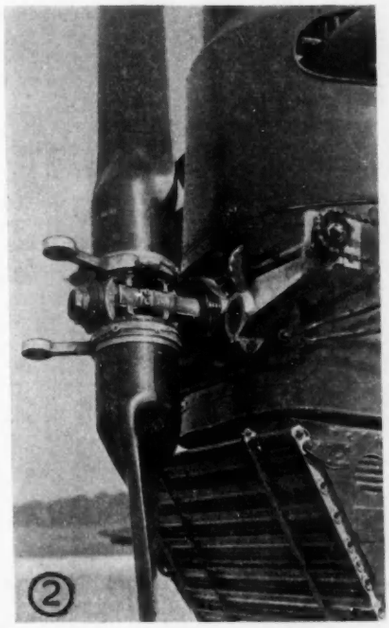

FIG. 2—ARMY AIR CORPS CONTROLLABLE PROPELLER INSTALLED ON AN AIRPLANE

This Was Evolved in the Course of Years of Experimenting. Aluminum-Alloy Blades Have Hollow Shanks Fitting Over Steel Extensions from the Hub and Mounted on Frictionless Bearings. Centrifugal Counterweights Reduce the Load on the Intermediate Control-Unit, Which Is Screw-Actuated. Cables Connect the Blade Control-Unit with Controls in the Cockpit, Where a Pitch Indicator Is Located

Another controllable propeller in which the method of changing the pitch was closely related to that used by the Army was submitted for test by the Navy. This is shown in Fig. 4. It was manufactured by Mr. Hart. The outstanding feature of this propeller was that the pitch of the blades could be increased sufficiently so that the propeller could be feathered and also could be reversed for reverse thrust. The propeller was designed primarily for use on airships.

A type of propeller that is entirely different from that on which the Engineering Division of the Air Corps had been working is shown in Fig. 5. This was submitted by Spencer Heath, of the American Propeller Co., in 1919. Through a system of gearing built into the propeller, the pitch could be

increased or decreased by holding one or the other of two brake-drums. The brake bands were to be actuated from the cockpit. Engine power was employed to effect the actual changing of the pitch. The propeller blades could be turned 360 deg. in their sockets, and hence were capable of being "feathered" into the airstream to eliminate "wind-milling" and of being reversed when reverse thrust was needed. This was the first feathering propeller to come into the experience of the Division. In a subsequent redesigned propeller of this type which was tested, a very ingenious though quite complicated pitch-indicating mechanism was included.

A still different type of controllable propeller (Fig. 6) manufactured by the Helix Propeller Co., of Germany, and known as the Reisner controllable, was submitted through the National Advisory Committee for Aeronautics and was tested by the Engineering Division in 1924. This was to be operated by power from the engine communicated through a pair of rubber-tired wheels attached to the propeller and apparently intended to roll on circular tracks that could be engaged with and disengaged from the wheels by means of controls extending into the cockpit. No tracks or control mechanism were received with the propeller. Attached to each wheel was a screw carrying a threaded block engaging with the blade so that, as the block was forced along the screw, the blade was turned to different angles. A small gear keyed to the opposite, or front, end of each screw meshed with a larger gear, mounted concentrically with the engine shaft, which served to keep the blades synchronized as to pitch.

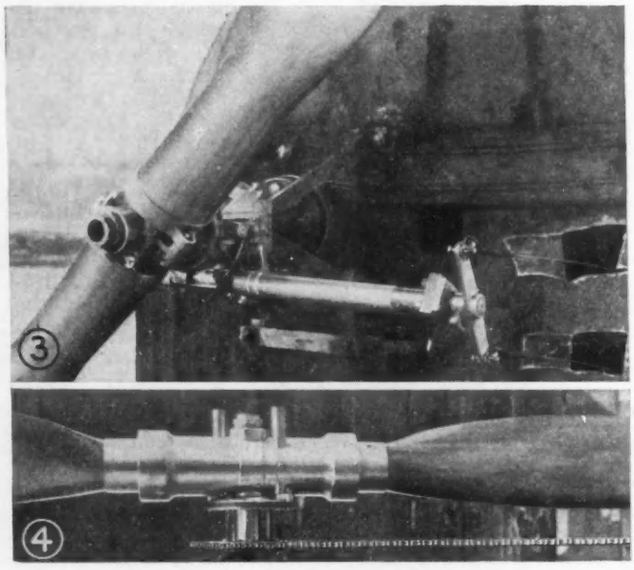

FIG. 3—STANDARD STEEL PROPELLER CO. CONTROLLABLE PROPELLER MOUNTED ON A TEST ENGINE

The Scheme of Changing the Blade Pitch Is Similar To That in Fig. 2. The Blades Were of Steel, Made Hollow for Lightness and Supported on Hub Stubs. All Bearings Were Encased in the Hollow Blade-Ends. Centrifugal Counterweights Were Not Employed When This Design Was Built, and Increasing the Pitch When the Propeller Was Running at High Speed Was Very Difficult. Excessive Force Required To Hold the Blades at Normal Pitch-Setting Imposed a Heavy Continuous Load on the Intermediate Running Bearing

FIG. 4—HART CONTROLLABLE PROPELLER DESIGNED FOR THE NAVY

This Was Designed Primarily for Use on Airships. The Method of Changing the Blade Pitch Is Closely Allied to That in Figs. 1 and 2, but the Pitch Could Be Increased Enough To Feather the Blades or Reverse Their Thrust

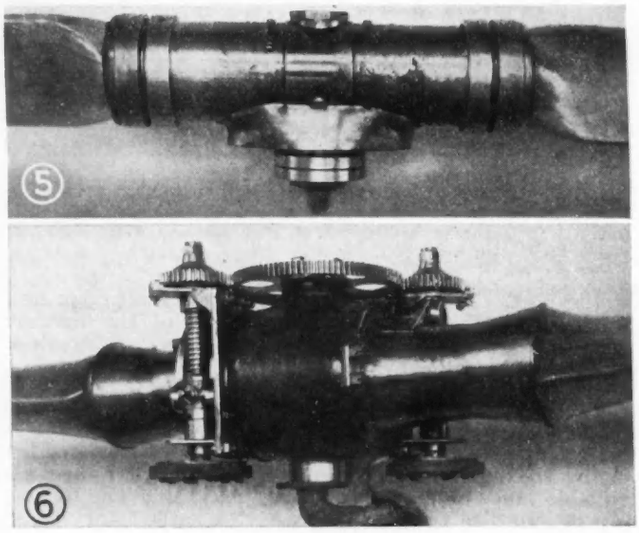

FIG. 5—HUB PORTION OF SPENCER HEATH CONTROLLABLE PROPELLER

Blade Pitch Was Increased or Decreased by Engine Power Transmitted through a System of Gearing Built into the Hub, Brake Bands Actuated from the Cockpit Holding One or Other of Two Brake-Drums. The Blades Could Be Turned 360 Deg. in Their Sockets, and Hence Could Be Feathered, To Avoid Windmill Effect, or Reversed

FIG. 6—HUB PORTION OF GERMAN REISNER CONTROLLABLE PROPELLER

This Was Designed To Be Operated by Power from the Engine Transmitted through a Pair of Rubber-Tired Wheels Rolling on Circular Tracks That Could Be Engaged and Disengaged. Each Wheel Turned a Screw Carrying a Block Connected with One Blade by a Link. The Blades Were Synchronized as to Pitch by Spur Gears

An interesting later type of controllable propeller is embodied in the design of the Smith Engineering Co., of Cleveland. This propeller has hollow steel blades which are retained in the hub by multiple-race ball-bearings, as seen in Fig. 7. The blades can be rotated through 360 deg. about their axis by a system of worms and gears carried in the hub and operated by a servo mechanism controlled by the pilot. The propeller is 9 ft. in diameter, weighs 113 lb. complete, and is designed especially for mounting on the 450-hp. Pratt & Whitney Wasp engine. The engaging device for the servo mechanism is carried in a small assembly that replaces the thrust-bearing cover-plate of the engine. The hollow steel blades are of the Dicks type and are made by the Pittsburgh Screw & Bolt Corp.

Electrically Operated Controllable Propeler

On Sept. 25, 1928, the Materiel Division tested a propeller submitted by Thomas Duprey, in which the pitch of the blades was changed by means of power derived from an electric motor mounted on the hub and concentric with its axis of rotation, as shown in Fig. 8. Electric current was transmitted from a battery to the motor through slip-rings and brushes. Control was effected by making proper electric contacts in the cockpit.

Centrifugally Operated Controllable Propeller

The design of the Southern Aircraft Corp., of Birmingham, Ala., shown in Fig. 9, may be termed a "three-position" controllable propeller. It provides selection of any one of three pitch-angle settings, which

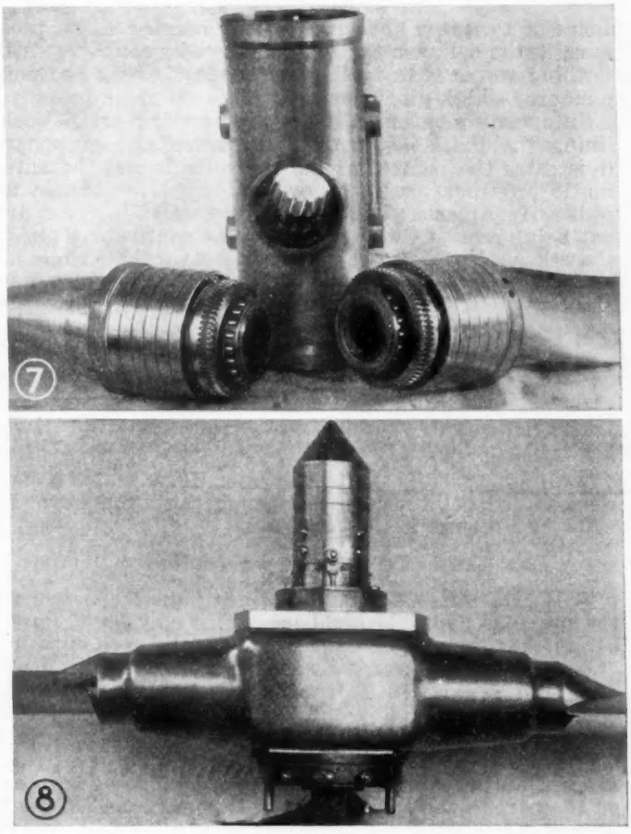

FIG. 7—HUB AND BLADE ENDS OF SMITH ENGINEERING CO. CONTROLLABLE PROPELLER

Hollow Steel Blades Are Retained in the Hub by Multiple-Race Ball-Bearings. They Are Rotated by Means of Worms and Gears in the Hub, Operated by a Servo Mechanism Controlled by the Pilot. This Propeller Was Designed for Use with the 450-Hp. Wasp Engine, the Engaging Device for the Servo Mechanism Being Carried in a Small Assembly That Replaces the Thrust-Bearing Cover-Plate of the Engine

FIG. 8—HUB PORTION OF DUPREY CONTROLLABLE PROPELLER

An Electric Motor Mounted on the Hub, Concentric with Its Axis of Rotation, Provided the Power for Changing the Blade Pitch. Current Supplied by a Battery Was Transmitted through Slip-Rings and Brushes, and Control Was Effected by Making Electrical Contacts in the Cockpit

may be designated low, intermediate and high. The blades are conventional and of forged duralumin. They are actuated by coil springs and counterweights, both the springs and the counterweights being so proportioned that, at propeller speeds above a given rate of revolution, centrifugal force developed by the counterweights exceeds the tension in the springs, the opposing blade-forces and the friction. To increase the pitch angles from low to intermediate to high, the propeller must be rotating at some speed greater than the given rotational speed, and, to decrease the angles, the propeller must rotate at some speed below a given rate. The speed above which the blade angles can be increased is considerably higher than the speed below which the angles can be decreased. This characteristic, which may be termed lag, is due to the fact that, in increasing the pitch angles, the counterweights must develop a force sufficiently in excess of the tension in the springs to overcome friction and the centrifugal moment developed in the blades. The counterweight arms normally are locked in one of three positions, control being effected by the engagement of a stationary roller with a lock cam on the hub. Engagement of the roller unlocks the counterweight arm and permits it to move to the next higher or lower position, where it is again locked in position. Full control of the propeller is effected by manipulating the cockpit control lever and varying the rotational speed of the engine.

Hydro-Centrifugally Operated Controllable Propeller

An unusual type of controllable propeller, shown in Fig. 10, is being developed by the Hamilton Standard Propeller Corp. At present this is a two-position controllable, and both hydraulic pressure and centrifugal force are utilized in its operation. Centrifugal force developed in a specially proportioned but simple system of weights and linkages serves to hold the pitch of the blades at their higher value at all speeds. Only by introducing oil under pressure into an oppositely acting cylinder is the pitch of the propeller changed from its higher to its lower position. The cylinder is of suffi-

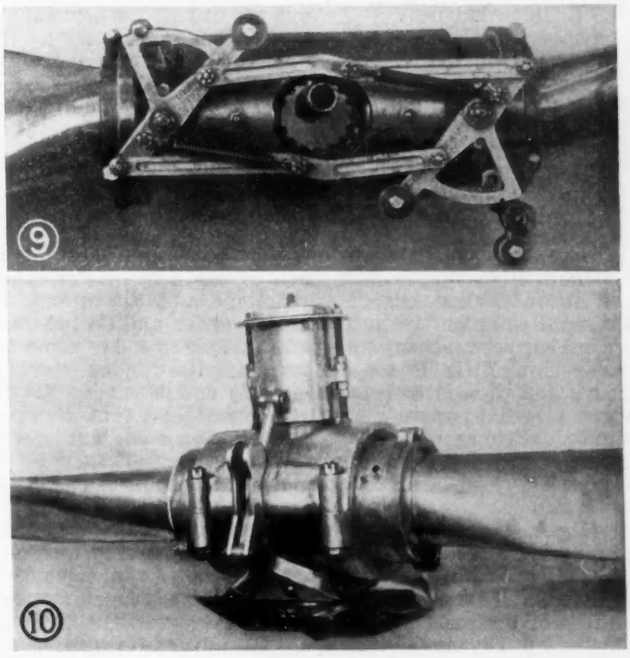

FIG. 9—HUB OF SOUTHERN AIRCRAFT CO. CONTROLLABLE PROPELLER

This Is a Three-Position Propeller the Duralumin Blades of Which Are Actuated through Counterweights and Springs by Changes in Speed of the Engine. When the Propeller Speed Exceeds a Given Rate of Revolution, the Centrifugal Force of the Counterweights Overcomes the Tension of the Springs, Opposing Blade-Forces and Friction and Increases the Pitch. To Decrease the Angle, the Speed Must Drop Below a Given Rate. The Counterweight Arms Are Locked in One of Three Blade-Positions and Control Is Effected by Engaging a Stationary Roller with a Lock Cam on the Hub

FIG. 10—HUB AND BLADE ENDS OF HAMILTON STANDARD PROPELLER CORP. HYDRO-CENTRIFUGALLY OPERATED CONTROLLABLE PROPELLER

Centrifugal Force Developed in a System of Weights and Linkages Holds the Blades at Their Higher Pitch at All Speeds. Oil Introduced under Pressure from the Engine into an Oppositely Acting Cylinder Overcomes the Centrifugal Force and Reduces the Blade Pitch to the Lower Position. The Cylinder, Rather Than the Piston, Is Moved by the Oil. A Three-Way Valve Controls the Pressure in the Cylinder, Which Is in Front of the Hub, and Serves To Decrease the Pitch or To Permit the Centrifugal Force To Increase It

ciently generous proportions so that oil at only the ordinary pressures used in engines generates ample force to overcome the centrifugal action and change the pitch to the lower value. The cylinder is mounted on the front of the propeller hub and is a part of the moving system, the piston being fixed in its location. Oil is tapped from the lubricating system and led to the control cylinder through the center of the shaft. A special gland around the shaft inside the crankcase aligns with a transverse hole communicating with the longitudinal hole in the center of the shaft. A three-way valve connects this passage-way leading to the cylinder either to the oil-pressure system of the engine to decrease the pitch or to the sump to permit the centrifgual force to increase the pitch. Failure to develop sufficient oil pressure in the cylinder for control purposes could result in nothing worse than having the blades held in the non-dangerous high-pitch position.

Information given in a very interesting article[2] outlining the British viewpoint on controllable propellers illustrates the point that the controllable and the automatic propeller are being worked upon in Europe as well as in America, and that the problems involved are not being more readily solved on one continent than on the other. However, we may safely state that, while an entirely satisfactory controllable propeller is not yet in sight, a few designs that will be useful in certain specific application will soon be available.

THE DISCUSSION

E. H. SHERBONDY[3]:—I wonder if any of the aeronautic people are familiar with the Kaplen hydroelectric turbine[4] in which the pitch of the buckets is varied with the gate opening. This came into use in Europe some half-dozen years ago and in the last three or four years has been in prominent use here. The means for varying the pitch is automatic. I think it would be of great interest to aeronautic engineers.

Automatic Propellers Await Development

EDWARD P. WARNER[5]:—All of the propellers mentioned in the paper have been of the controllable type. Will Mr. Dickey enlarge a little on the status of experimental work on the automatic propeller and on his own confidence, or otherwise, that it may some day come to something? In European countries the tendency every now and then is to become greatly excited about it. A great deal of money has been spent in Great Britain and in France in the last six years on some automatic propellers, though I am not sure whether they have come into use or have got no farther than the testing stand.

D. A. DICKEY:—Automatic features make the construction much more involved, and I think that, in general, inventors have been inclined to try to solve the controllable-propeller problems before launching on those of the automatic propeller. However, the Eclipse Aviation Co. is working on an automatic propeller, which I understand has been flown, but we are not at liberty to reveal anything regarding it at the present time.

The Air Corps has been trying to encourage development of the automatic propeller. The need for the automatic propeller in pursuit work is very great, and, as a result, we should see some interesting developments along that line probably in the next two years. As stated in the paper, permission to publish information regarding some of the later types that have been tested at Wright Field has been refused.

CHAIRMAN E. E. WILSON[6]:—It is no secret, however, that the automatic propeller is being flown in this Country and has considerable promise, but it has not reached the point where the Bendix Aviation Corp. is willing to release it for general use.

Aim Is To Increase Speed Range

J. H. GEISSE[7]:—A point that one of the discussers of the previous paper[8] brought up, which may be of interest, is that the aim of the aeronautic engineer is to increase as far as he can the range between stalling speed and high speed. As this range is increased year by year, the need for adjustable propellers becomes much more pronounced.

About a year ago one manufacturer was greatly in need of an adjustable propeller or a change of opinion on the part of the Department of Commerce. After his propeller had been set for normal operation, he found that, with his landing-gear retracted, the engine speed increased considerably beyond the speed that the Department would allow; so he had to change the pitch of the propeller, which considerably affected his take-off.

CHAIRMAN WILSON:—A great deal of attention is being focused on that right now. As the speed range increases, the climbing characteristics of airplanes vary until we get into complications of length of landing-fields. High-speed airplanes, when heavily loaded, advance a great distance before they gain much altitude, and it becomes something to worry about.

Can Mr. Dickey give us any information, in a quantitative way, indicating how much advantage would result from a three-position over a two-position controllable pitch which gives the optimum cruising setting?

MR. DICKEY:—Any of those features can be tested fairly well by setting the adjustable-pitch propeller for the conditions under which you want to get data, so long as the setting is not so detrimental that you cannot get the plane off the ground. You can set the pitch low and test the take-off and climb, and you can also set it a little high and check on cruising.

Some tests were made by the Materiel Division on an O-2H, an observation-type airplane with a Liberty engine and a controllable propeller. With the standard non-controllable propeller, this airplane had the following performance at sea level: 132 m.p.h. at 1715 r.p.m. in level flight; a rate of climb of 903 ft. per min. at 1560 r.p.m. and 78 m.p.h.; a cruising speed of 106 m.p.h. at 1440 r.p.m., with a fuel consumption corresponding to 4.5 miles per gallon; a range of 488 miles; and an endurance of 4.6 hr. One adjustment of the propeller giving a slightly higher cruising velocity at a low engine-speed—109 m.p.h. at 1300 r.p.m.—resulted in a performance of 4.7 miles per gallon, 512 miles' range, and an endurance of 4.7 hr. Another adjustment at slower velocity—97 m.p.h. at 1200 r.p.m.—gave a considerably better fuel economy of 5.4 miles per gallon,

[2] See *Journal of the Royal Aeronautical Society of Great Britain*, March, 1931, p. 231.

[3] Cleveland.

[4] See paper on Present Day Hydro Power Practice in Central Europe, by A. V. Karpov, presented at the Summer convention of the American Institute of Electrical Engineers in Toronto, 1930. Abstracted in *Power*, July 15, 1930, p. 108.

[5] M.S.A.E.—Editor *Aviation*, New York City.

[6] M.S.A.E.—President, Sikorsky Aviation Corp., Bridgeport, Conn.

[7] M.S.A.E.—Vice-president of engineering, Comet Engine Corp., Madison Wis.

[8] See Aeronautic Propeller Design, by F. W. Caldwell, *Aviation Engineering*, January, 1932.

581 miles' range, and an endurance of 6 hr. By reducing the pitch the run for take-off was reduced from the normal 850 ft. to 720 ft. and the rate of climb was increased from the 903 per min. given above to 1022 ft. per min. With the setting that gave the best fuel economy, the run for take-off was 1400 ft.

Two versus Three Settings for Transports

CHAIRMAN WILSON:—The reason I asked the question is this: With two positions of the propeller available we can set the low-pitch position for best take-off and the high-pitch for best high speed or cruising speed. In transport work, our two major requirements are take-off and cruising speed, rather than high speed.

MR. DICKEY:—I believe that the high-speed position should not be neglected if it can be included, because there will always be times when the pilot will want to get all he can out of the plane; he would not want to sacrifice available high speed for most economical cruising speed.

D. E. OLSHEVSKY[9]:—The efficiency does not change much after cruising speed is attained. The change is much less pronounced in the higher than in the lower speeds; therefore two settings would practically cover the range of high speed.

MR. DICKEY:—I believe that the difference in efficiency between the cruising and the high-speed conditions is not the prevailing factor; the problem is to get the maximum power out of the engine. Even if the propeller should be less efficient at high speed, some of its efficiency can be sacrificed if the engine speed can be increased so as to give more power.

There is a pronounced difference in engine revolutions per minute between a good cruising speed and a high speed, and the difference in revolutions represents fairly well the difference in power available for the two conditions. If an engine is cruised ordinarily at about 80 per cent of full throttle, the available power of the engine is cut almost in proportion.

MR. OLSHEVSKY:—The problem is to get more power out of the propeller. With normal engines the net output-power differences, at high speed, between a cruising-speed and a high-speed blade-setting are small. The gain in each case depends upon the actual flight characteristics of the engine, the propeller and the airplane.

The third setting is highly desirable with supercharged engines, particularly at high altitudes. For ordinary purposes, if the third setting involves complications, it might be desirable to have only the take-off and the cruising-speed setting. Are you in favor of three settings?

MR. DICKEY:—I am not in favor of only two positions if, with a reasonable amount of additional mechanism, three positions can be included.

Advantage of Reducing Pitch in Multi-Engine Airplanes

THOMAS S. KEMBLE[10]:—May not the amount of excess power required to be put into the multi-engine ship, with or without three propeller-blade positions, be fully as important as the efficiency as measured in miles per gallon? It would be of interest to learn how great would be the practical effect of a propeller-blade feathering position for the propeller of a stalled engine in a multi-engine ship.

CHAIRMAN WILSON:—We have not touched on that particular point of usefulness of controllable-pitch propellers. In the multi-engine airplane, it is clear that, with the loss of a part of the powerplant, we not only lose the power of that engine but also a portion of the power availablel in the remaining engine or engines, and, by the use of the controllable propeller, which enables us to speed up those engines, we do get an advantage. A little more study would be required to determine whether two or three positions as applied to the propellers would be better.

Until I saw Mr. Dickey's paper, I had not thought of three positions in contrast with two positions, and the first thought that occurred to me was: With the controllable-pitch propeller we can use the minimum-pitch setting for best take-off, the second position for best high speed or best cruising, and, in any event, from the second setting in the high-pitch position we will throttle back.

Many variables enter into the cruising condition. Assuming that we throttle back from the second position, which gives us the best speed, to some cruising speed or throttle back from third position, which gives us some best cruising, to the cruising speed, would the complication be warranted by the possible advantage of having the third-pitch position? Probably that is a question which will need a little more study to answer specifically.

VAL CRONSTEDT[11]:—I am familiar with a series of tests that have been run on propellers that may answer your question. The object of these tests was to find the most satisfactory blade-angle setting for cruising speeds on a given airplane, and speed tests were made with the propeller set at angles permitting different engine speeds over a range of approximately 1000 r.p.m. from 1000 to 2000, keeping the power input into the propeller at a constant value with the throttle. These tests showed that only very slight variations in airplane speed occurred with these various settings, and it appears to me that in the end this matter resolves down to settling the rather indefinite figure of desirable cruising speed for certain engines in revolutions per minute.

F. W. CALDWELL[12]:—If there is any hope of flying the multiple-engine plane on less than the total number of engines installed, it must have considerable reserve power, so the take-off will have to be reasonably satisfactory under those conditions. When the two-position propeller is used for that type of application, the low-pitch setting would be the one corresponding to the best operation with one engine idle rather than to the best take-off.

CHAIRMAN WILSON:—That whole point came to a head in connection with a certain multi-engine or twin-engine airplane, in which type the Department of Commerce requirement is that the ship shall be able to maintain its altitude with one engine dead. With two engines and one dead, a little more than one-half of the power is lost. In this particular airplane, the gross weight necessary to meet the operator's requirements was just a little too much for the ship to carry with one engine idle.

It is interesting to see from all this that propeller development is rapidly being accelerated and designers are doing their best to keep pace with recent developments that call for different classes of material, such as alloys of magnesium and aluminum and hollow steel.

[9] Research department, Goodyear-Zeppelin Corp., Akron, Ohio.

[10] M.S.A.E.—Chief engineer, Pennington Engineering Co., Cleveland.

[11] Assistant chief engineer, Lycoming Mfg. Co., Williamsport, Pa.

[12] M.S.A.E.—Vice-president, chief engineer, Hamilton Standard Propeller Corp., Homestead, Pa.

Magnesium Alloys in Aircraft-Engine Construction

20th National Aeronautic Meeting Paper

By G. D. Welty[1]

ACHIEVEMENTS of the last ten years in increasing the power-weight ratio of aircraft engines are stated and contributing factors are analyzed. Aluminum alloys have replaced cast iron and steel for certain parts, not entirely because of their lower weight but because of a combination of properties which better fit them for the task. Similar considerations must govern the replacement of aluminum-base alloys by those of magnesium. The most promising immediate field for the magnesium alloys is said to lie in applications wherein strength and lightness are the main considerations and high-temperature properties are of secondary importance.

Properties of magnesium castings and forgings are compared with those of castings and forgings of the aluminum alloys. Features of design are discussed which should receive special attention when changing a part from aluminum to magnesium.

Machining practices for magnesium are covered in some detail. The author states that the present casting-alloys have proved commercially satisfactory as to corrosion for most types of land service. In salt-water service, especially in tropical countries, a certain amount of trouble has been encountered and some protective measures seem to be necessary. A recommended treatment for protection against corrosion is offered.

Discussion of the paper touched on corrosion, including the effects of contact with wood and with gaskets; on machining and heat-treatment; and on the rapid improvement that is being made in magnesium.

REDUCTION in weight—or, more accurately, increase in power-weight ratio—continues to be one of the major problems confronting the aircraft-engine designer. During the last ten years we have seen the accepted figure of 3 lb. per hp. fall steadily to 1½ lb., and developments of the last year indicate clearly that the goal of 1 lb. per developed horsepower will be attained in the not far distant future. Three factors that have contributed substantially to this accomplishment are: (*a*) the introduction of new and more efficient designs, (*b*) improvement in fuels and (*c*) substitution of lighter materials for heavier ones. The present discussion falls under (*c*) and relates particularly to the substitution of magnesium-base alloys for those of aluminum.

When one material replaces another in aircraft-engine construction, it usually is because the new material possesses a more desirable combination of properties for the function than did the old. Thus, cast iron has been replaced by aluminum for such parts as crankcase sections, cylinder-heads and pistons; while steel forgings have, in a number of instances, given way to strong-alloy aluminum forgings. These substitutions have been made because of the relative lightness and high thermal conductivity of aluminum, combined with sufficient strength and rigidity to render satisfactory service.

No one would think of aluminum as a possible substitute for steel as a crankshaft, valve or piston-pin material because, although lightness is certainly desirable in a crankshaft and high thermal conductivity in a valve, aluminum lacks numerous other properties required to function satisfactorily in these parts. Similar considerations govern the displacement of the aluminum-base alloys by those of magnesium. The lighter material with a potential weight saving over aluminum of from 25 to 30 per cent will surely establish itself in places where it is best fitted to perform the task; but the replacement will not be a wholesale one, and the eventual result will be an engine utilizing many more metals and alloys than are employed at present, each particularly adapted to the performance of its specific task.

In presenting a paper on light alloys at a similar meeting two years ago, I ventured the prediction that the magnesium alloys would find wide application for parts operating at relatively low temperatures where strength and lightness are the main considerations and where high thermal conductivity is of secondary importance. This field—including all such pieces as crankcases, nose sections, blower sections, drive housings and oil sumps—still seems to be the most attractive one for the immediate application of magnesium. Examples of such parts are shown in Figs. 1 to 8. Let us consider certain features of design which should receive careful attention when magnesium parts are substituted for those of aluminum.

Magnesium Castings

The physical properties of magnesium casting alloy AM7.4 and aluminum alloy No. 195 are given in the first two columns of Table 1 for comparison. The com-

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TABLE 1—PHYSICAL PROPERTIES OF MAGNESIUM AND ALUMINUM ALLOYS

	Heat-Treated Sand-Casting Alloys		Forging Alloys		
	Magnesium AM7.4	Aluminum No. 195	Magnesium AM61S	Aluminum 51ST	Aluminum 25ST
Density	1.79	2.78	1.85	2.69	2.78
Tensile Strength, lb. per sq. in.	28,000-33,000	28,000-33,000	35,000-38,000	45,000-50,000	55,000-63,000
Yield Point, lb. per sq. in.	9,000-11,000	12,000-14,000	20,000-24,000	30,000-40,000	30,000-40,000
Elongation, per cent in 2 in.	9-12	6-10	8-12	10-18	16-25
Brinell Hardness, No.	50	75	40-50	90-100	90-110
Modulus of Elasticity	6,500,000	10,000,000	6,500,000	10,000,000	10,000,000
Endurance Limit, lb. per sq. in.	9,500	6,500	14,000	10,500	15,000

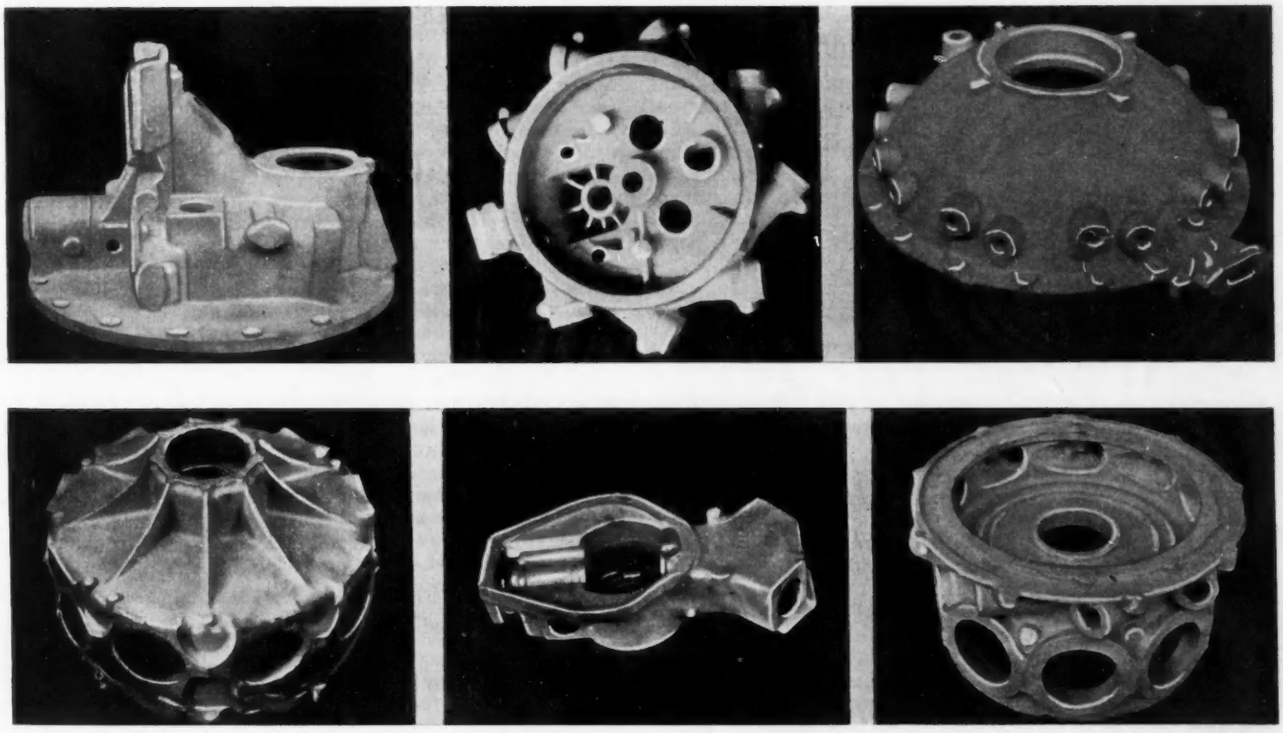
position of the former is 7 per cent of aluminum, 0.4 per cent of manganese and the remainder of magnesium. This corresponds closely with the composition used by all foundries supplying magnesium castings of this type to the aircraft trade. No. 195 alloy, or its equivalent, is the customary aluminum composition for the same type of service. It will be noted that the magnesium alloy is equal to the aluminum in tensile strength, somewhat inferior in yield-point and rather better in elongation. Its Brinell hardness is 50 and the modulus of elasticity 6,500,000, as compared with 75 and 10,000,000 for aluminum. The magnesium is distinctly superior to aluminum in fatigue-endurance limit.

As endurance limit is a governing factor in the design of parts subject to repeated stress, it might be assumed that a certain part which has proved satisfactory as an aluminum casting could certainly be counted on to stand up as a magnesium casting. However, trouble has sometimes been experienced when such substitutions have been made using the same pattern equipment and machining practice as for aluminum. Magnesium is more sensitive than aluminum to small fillets and sharp corners, probably because its lower elastic modulus permits a greater deformation under a given load, resulting in a greater concentration of stresses at such points. This difficulty can usually be eliminated by providing generous fillets in the castings and by employing careful machining practice, but it is necessary in some instances to increase the section in magnesium castings by about 15 per cent to make the stiffness equal to that of aluminum. It is not necessary to add metal all over the casting but only at critical sections where excessive deformation might occur. Therefore the additional volume usually does not amount to more than 5 to 7 per cent, resulting in a net weight saving over aluminum of 25 to 30 instead of 30 to 35 per cent.

Necessary changes in aluminum pattern-equipment for the production of satisfactory magnesium castings can usually be made at relatively small cost. The shrinkage allowance is 1/64 in. per ft. greater than for aluminum, but this usually gives no trouble unless the particular casting is quite long. As magnesium castings are much softer than those of aluminum, it is sometimes necessary to increase the number or size of studs. Where pressures are heavy larger seats are desirable for bolt heads and washers. When these matters were properly taken care of, magnesium castings have demonstrated their ability to stand up satisfactorily over long periods under severe conditions of service.

Magnesium Forgings

Up to the present, there has been very little commercial application of magnesium-alloy forgings because the art of producing them was not sufficiently advanced. Much progress has been made recently in this art, however, so that it is now possible to forge in magnesium virtually any shape that can be produced as an aluminum-alloy forging. The last three columns of Table 2 give the physical properties of magnesium forging alloy 61S and aluminum alloys 51ST and 25ST. Alloy 51ST is commonly used for such forgings as crankcase sections, nose sections and bearing plates, while 25ST is required for very highly stressed parts such as connecting-rods for in-line engines, link rods for radial engines, and propeller blades. In comparing the two alloys 61S and 51ST, it will be noted that all the properties of the magnesium composition excepting the endurance limit are lower. This is distinctly higher; in



EXAMPLES OF MAGNESIUM-ALLOY CASTINGS

Fig. 1—Rear Cover of Crankcase, AM7.4 HT Alloy, 19 Lb.

Fig. 2—Blower Section, AM7.4 HT Alloy, 30 Lb.

Fig. 3—Crankcase Front Cover, AM7.4 HT Alloy, 15 Lb.

Fig. 4—Crankcase of Diesel Aircraft Engine, AM7.4 HT Alloy, 40 Lb.

Fig. 5—Gearcase, AM7.4 HT Alloy, 7 Lb.

Fig. 6—Crankcase for Nine-Cylinder Engine, AM7.4 HT Alloy, 33 Lb.

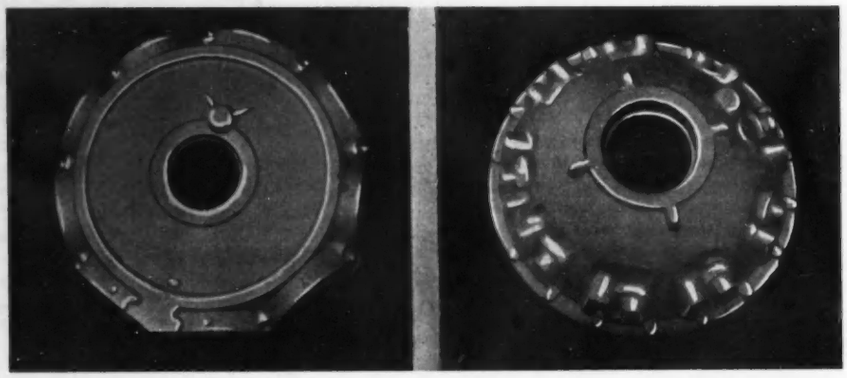


FIG. 7—EXPERIMENTAL CRANKCASE-HALF FORGING, AM61S ALLOY, 18 LB.

FIG. 8—NOSE-PIECE FORGING, AM61S ALLOY, 12.7 LB.

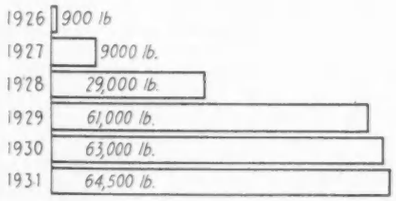


FIG. 9—MAGNESIUM CASTINGS USED IN AIRCRAFT IN THE UNITED STATES

Amount for 1931 Estimated from Consumption for the First Six Months

fact, it is nearly as high as that of 25ST, which possesses almost twice the ultimate strength and yield point. This high endurance limit is characteristic of the magnesium alloys and is one of their chief assets.

What has been said about design alterations in connection with magnesium castings is even more pertinent in the case of magnesium forgings. Experience to date plainly indicates the necessity of enlarging the magnesium forging sufficiently to make it equivalent to the aluminum part in stiffness. Forgings usually are rather highly stressed, and the lower hardness, modulus and yield point are at once apparent when magnesium forgings are substituted for those of aluminum without the necessary changes in design. Large bearing surfaces with low unit pressures are of course indicated when parts are bolted together. Liberal-sized bosses should be provided for studs, which should not be driven too near a hole or an unsupported edge.

Magnesium forgings do not hold much promise as a connecting-rod material, but the picture is much brighter for propeller blades. A considerable number of magnesium propellers have been tested, with very promising results. The low density of the material, coupled with its high endurance limit, gives a desirable combination of properties. The required degree of blade stiffness must of course be obtained by employing sections of sufficient thickness. Numerous experiments now under way undoubtedly will lead to successful commercial applications of magnesium forgings for propeller blades.

Machining Practice for Magnesium

Magnesium and magnesium alloys can be classed among the more easily machined metals. Proper tools and methods are of course necessary, and an understanding of some of the principles and requirements will help the machinist to solve his specific problems. Owing to the wide differences in problems encountered in machining, no attempt will be made to cover all details; much depends upon the design of the tools, the type of work, and the personal equation of the machine-tool operator.

The machining characteristics of magnesium are often confused with those of aluminum, owing to the fact that both are light metals and have some similarity in color and appearance. Cutting-tools for magnesium should be provided with even less top rake or hook and less side rake than have tools for cutting steel; in many instances they should have little, if any, top and side rake, corresponding closely to those for machining brass. Unlike tools for brass, which usually are ground with a rather coarse abrasive wheel, magnesium-cutting tools should be finished with a fine abrasive wheel and the edges should be dressed with an oilstone to remove burrs, wire-edges or grinding-wheel marks.

The foregoing recommendations apply particularly to lathe, planer and shaper tools. The same requirements also obtain to a certain extent for tools of most other types, including special forming-tools, milling-cutters, drills and threading-tools. Milling-cutters of the spiral-fluted type, such as are used for steel, are recommended for magnesium. It is important, however, that coarse-tooth cutters be used. Reamers for either hand or power reaming should also be spiral-fluted. The ordinary twist-drill works very satisfactorily. A comparatively heavy feed can be used, with speeds approximately the same as for drilling brass. Taps such as are used for steel can be used for tapping threads in magnesium. Magnesium can be sawed very readily with band or power saws. High-speed metal-cutting band-saws operating at speeds of about 5000 ft. per min. or circular saws operating at speeds of about 10,000 ft. per min. can be used. A coolant such as soluble cutting-compound is used with these speeds to decrease the fire hazard.

In general, cutting-speeds approximating those for brass may be used for magnesium. Fairly heavy feeds and deep cuts can be used for roughing cuts in many classes of work. Light cuts are necessary for fine-finish work. It should also be appreciated that magnesium springs away from the tool more than do most other metals; this makes light cuts especially necessary when turning the more flexible parts where the ratio of length to diameter is high.

A lubricant or cutting compound is unnecessary for many of the more simple machining operations such as turning, but a lubricant or coolant is often desirable for drilling, tapping and screw-machine work. A mixture of about equal parts of lard-oil and kerosene has been found quite satisfactory for this purpose in some cases. A fire hazard exists in cutting operations where heat is likely to be generated and the cuttings are very fine, and a coolant such as soluble cutting-compound is then necessary.

Carbon tool-steels can be used successfully for machining magnesium, but high-speed tool-steels are preferable for production work. Advantages accrue from the use of the more recent tungsten-carbide tools, the same as for other metals.

Corrosion Resistance Improved

Not many years ago, magnesium-alloy castings were regarded as so unstable and corrodible that they were not believed to be dependable for engine parts. Improvements in alloys, together with more advanced foundry technique, has done much to dispel this early opinion.

So far as atmospheric corrosion away from the seaboard is concerned, magnesium castings and forgings may be considered as having a high degree of corrosion resistance. Tests conducted over a period of years have

shown that the mechanical properties of these alloys are not affected by atmospheric exposure. No instances of intercrystalline corrosion have been noted. This fact is of considerable practical importance, as it makes possible estimating the extent of corrosion on an engine part by visual inspection.

Magnesium-alloy castings and forgings are not recommended for service where they will be subjected to immersion in sea water. Salt air and salt spray also are destructive to unprotected magnesium-alloy parts, particularly in tropical latitudes. For this reason, if magnesium castings are to be used on seaplanes or on airplanes operating on the seaboard, they should be protected by some suitable means.

Treatment To Resist Corrosion

The following practice is recommended for protection against corrosion:

Cleaning.—(*a*) Rough castings or forgings should be dipped in a 25-per-cent solution of sulphuric acid. The action of this solution is quite rapid, and parts should not be left in it longer than about 5 sec., or a sufficient time to produce a good etch; or (*b*) on finished surfaces which must be held to accurate dimensions, a 4-per-cent solution of sodium hydroxide should be substituted for the acid dip. The temperature of this bath should be maintained between 175 and 195 deg. fahr. The time allowed in the bath may be 5 min.; or it may be longer with no ill effects. Upon removal, the parts should be rinsed in clear, cold water.

Phosphate Treatment.—The parts are now transferred to the phosphate bath containing phosphoric acid (syrupy), 1 lb.; magnesium oxide, 3 oz.; and water, 1 gal. The temperature of the bath is maintained at about 125 deg. fahr. The time of treatment is 1 hr., after which the parts are removed, washed with clean water, and dried.

Painting.—After the phosphate coating has been applied, parts may be painted or varnished according to individual requirements. Good results have been obtained by applying two coats of spar varnish, each coat being air-dried and baked at 200 to 250 deg. fahr. Additional protection is obtained and the original silvery color is restored if the spar varnish is pigmented with aluminum powder.

While this treatment will not afford complete and indefinite protection against corrosion, magnesium parts so treated will resist the action of salt air and salt spray at least five or ten times as well, under similar conditions, as will untreated pieces.

Fig. 9 shows the rapidity with which the use of magnesium-alloy castings by the aircraft industry has been increasing during the last five years. It is worthy of note that the total volume has continued to increase slightly, during even the last two years of business depression, when general production has suffered a large shrinkage. This clearly indicates that the industry is seeking the weight saving offered by magnesium and that it is ready to accept new magnesium products as they are perfected and made commercially available.

THE DISCUSSION

CHAIRMAN J. H. GEISSE[2]:—Magnesium is an illustration of the fact that reductions in the weight per horsepower of engines are due more to the metallurgist than to the engineer. Only a short time ago we thought that magnesium corroded so badly that it could not be used in engines. Few of us realize the strides that have been made since then.

Magnesium has been machined in our shop with practically no instructions and with no difficulty. Probably one-half of the workmen did not know that it was not aluminum.

A VISITOR:—Magnesium is used in Europe in the automotive industry because it is lower in cost than aluminum, according to my observation two years or more ago. We met failure when it was used next to wood.

G. D. WELTY:—Very little magnesium is used in automobile construction in this Country, so we have not met that problem. Probably the corrosion is caused by some mineral salt or other compound that is contained in the wood. The only similar thing that we have encountered is corrosion of magnesium under gaskets. We have found this to be caused by chlorides and sulphates, in the gasket material, which absorb water. When gasket manufacturers realize that problem they may be able to substitute materials that will not start corrosion.

K. W. STINSON[3]:—Is the heat-treatment of magnesium forging and casting alloys as critical as that of some of the aluminum alloys?

MR. WELTY:—Some of the magnesium alloys do not require any heat-treatment, and a number do require about the same nicety of control as aluminum alloys. Electric furnaces with accurate pyrometer control are required for good results.

ARTHUR NUTT[4]:—We have been using magnesium increasingly for the last five years, beginning with small parts like cover plates, gear covers and oil-pumps. The material has successfully replaced aluminum for such parts, and I believe that larger parts will be used as the cost becomes more nearly equalized with that of aluminum.

Magnesium has been improved more rapidly during the last few years than most people realize. Castings made five or six years ago would disappear with corrosion almost before you knew it. Without question, it will be improved even more rapidly during the next years.

CHAIRMAN GEISSE:—Only a few years ago an engineer placed a magnesium piston in water to find out how much it corroded. When next we looked for it, it had dissolved.

[2] M.S.A.E.—Vice-president of engineering, Comet Engine Corp., Madison, Wis.

[3] M.S.A.E.—Associate professor of automotive engineering, Ohio State University Columbus, Ohio.

[4] M.S.A.E.—Vice-president of engineering, Wright Aeronautical Corp., Paterson, N. J.

The Development of a Rear-Engined Streamline Car

Discussion of Sir Dennistoun Burney's Annual Meeting Paper[1]

DISCUSSION of the paper consists of questions written in the session, answers by the author, and two prepared pieces of discussion. The points raised relate to the designer's views with regard to use of an air-cooled engine, importance of aerodynamic design at moderate speed, effect of rear-end weight on steering at low speed, effect of a strong side wind, appearance of the streamline design, comparative gain in operating efficiency, whether calculations with respect to center of gravity and center of gyration should be made with car loaded or empty, why front wheels and fenders are not streamlined, effect of lift on weight distribution at high speed, fairing the under side of the car, reduction of wind noise, front-end stability, and independent springing.

A contributor of written discussion cites authority for holding that good aeronautic design does not require that the greatest cross-section shall be forward of the middle of the car and that the tail need not be long and tapered. He also asserts that the car should be streamlined in plan as well as profile. Another who submitted written discussion argues that mass distribution of the car, as analyzed by the author of the paper, should impair the steering, increase the tendency to sideslip and, when turning, throw the car into a sharper curve. The author answers all criticisms and points to performance as proof of the design.

CHAIRMAN W. T. FISHLEIGH[2]:—I am sorry that you all will not have an opportunity to ride in the latest design of Burney car and drive it at speed over bumps and around curves, as some of us were permitted to do yesterday. All of those who were with me agreed 100 per cent that it was rather a new sensation in a number of ways. The lack of bouncing effect in going over bad bumps, and the riding qualities, especially in taking curves at speed, are different from anything I have ever experienced in automobile riding or driving. The control of the car when driving it at speed, especially under rough conditions, and its "feel," as you might say, check with the theory that has been advanced by the author of the paper.

I will read the written questions, and Sir Dennistoun may answer them if he chooses. The first one is: What would you think of the air-cooled engine for your type of car?

SIR DENNISTOUN BURNEY:—At first I was very much in favor of the air-cooled engine, but my present opinion is that the water-cooled engine is likely to be more satisfactory, as I want the heat from the front radiator to warm the passengers in the winter. We have tried heating the front passenger compartment with exhaust heat, but it is not satisfactory. The only satisfactory way I have found is to obtain a very large flow of hot air, so that the driver and passenger can keep warm with both side windows open. I dare say it would be possible to work out a stream of hot air from the air-cooled engine, but we will let the designers of the engine do that.

QUESTION:—What troubles were experienced in steering at low speeds, due to the excess of weight on the rear end?

SIR DENNISTOUN:—No troubles were experienced, because it is not true to say there was an excess of weight on the rear end. My contention is that a weight distribution of twice the amount on the rear end as on the front end is correct and that the present weight distribution of the orthodox car, of even weight on the two axles, is incorrect.

Aerodynamic Efficiency at Moderate Speed

QUESTION:—How important is aerodynamic design at speeds below 45 m.p.h.?

SIR DENNISTOUN:—The improvement comes in at about 30 to 35 m.p.h., as at 35 m.p.h. the wind resistance in an orthodox car is equal to the rolling resistance. Above that speed, acceleration is increased and fuel consumption is reduced. The advantage of streamlining is largely a question of the cost of the fuel and the elimination of noise caused by rush of the wind around the body of the car. If you can save a certain amount of fuel even at 25 m.p.h., you may be 2 or 3 per cent ahead; at high speed, that saving may be something like 40 to 50 per cent.

QUESTION:—What would be the effect on the car, on a slippery road, with a strong side wind?

CHAIRMAN FISHLEIGH:—The question, as it has been put to me many times, suggests the query: Suppose you are driving past a large apartment building, next to a vacant lot or space, and you come suddenly from a protected position behind the apartment house into the full blast of a strong side wind, what will be the effect?

SIR DENNISTOUN:—That is a question on which one could go into considerable detail. We have hunted strong winds in England in order to get the correct answer to it. I have driven these cars at 80 m.p.h. in a very strong side wind, and they do not become unmanageable.

If speeds become higher, around 100 or 125 m.p.h., I believe it will be necessary to lengthen the wheelbase by 4 or 5 ft. and treat the design in much the same way as Sir Malcolm Campbell and Sir Henry Segrave had to do with their racing cars. But, for all practical driving speeds, we have had no more difficulty in controlling them in a side wind than in the orthodox car, and we have covered many tens of thousands of miles with these cars.

QUESTION:—For a given car weight, engine size, wheel size and axle ratio, what gain in operating efficiency is developed?

[1] The paper was published in the S.A.E. JOURNAL, February, 1932, p. 57. The author is a British Navy ex-officer resident in London, England, and was managing director in charge of the design of the British airship R-100.

[2] M.S.A.E.—Consulting engineer, Detroit.

SIR DENNISTOUN:—Some definite comparative figures were given in the paper from tests made by the Rolls-Royce company at its testing department at Derby. A comparison is rather difficult because of the difference in body space. The streamline car has an advantage, if the body space is the same, as the air resistance consumes 40 hp. against nearly 100 hp. for the same frontal area of the orthodox car at 77 m.p.h.; but, with less body space on the orthodox car, such as a close-coupled sedan, it is 40 hp. against 78.5 hp. for the orthodox car.

Dynamic Calculations Based on Half Load

CHAIRMAN FISHLEIGH:—I shall combine two questions. One has to do with the calculation with respect to the center of gravity; the other as to the calculation of values for radius of gyration.

QUESTION:—Are these calculations, as you have suggested them, to be made with the full passenger load or without?

SIR DENNISTOUN:—That brings out a very important point. I think the question goes further than whether the calculation is to be made with full passenger load or without; it is a question whether one should consider the sprung weight only or the car as a whole. My own view is that one should consider the car as a whole, because, when making a turn, the value of $AB = K^2$ is important from a road-holding point of view; and, furthermore, I think one can consider the car as a rigid beam having an elastic connection to the unsprung weight. I believe that most mathematicians, upon going into it, would agree that to consider only the sprung weight as affecting the vertical oscillations is not sound.

Passengers are, of course, sprung weight; which was mentioned in the paper. The longitudinal position of the center of gravity is hardly altered at all whether the car is loaded or is empty. In the conventional car, where the passengers are seated over the back axle, a considerable difference in the longitudinal position of the center of gravity is made when the car is full as compared with when it is empty. I think the total change of the streamline car is 2 per cent. Therefore one should, I think, make the calculation with the car half full, and consider the car as a whole and not only the sprung weight.

QUESTION:—Why are not the bumper and fenders and the front wheels streamlined?

SIR DENNISTOUN:—The bumper should be streamlined, but it is a detail which can be done at any time. I can buy the present bumpers cheap, and the others would be more expensive. If anyone can design a streamline wheel, I shall be pleased to have it.

The fenders do play quite an important part. We have had to make those in front close coupled and turn them over the wheels, because, with the position of the passengers, the front door shuts within 1 to 1¼ in. of the fender. If that fender were streamlined, we could not have a front door.

Lift Effect Negligible at Present Speeds

QUESTION:—What is the effect of lift on weight distribution at high speeds?

SIR DENNISTOUN:—Our present car has a lift of about 109 lb. at 60 m.p.h. I think the figures are 59 lb. at the back and 50 lb. at the front. That lift varies with the square of the speed. I do not think that will become a problem until the speed exceeds about 125 m.p.h.

QUESTION:—Does correct aerodynamic streamlining help to reduce wind noise at high speeds?

CHAIRMAN FISHLEIGH:—I wish you had all been able to be with us yesterday as we drove around Belle Isle at speeds from 50 m.p.h. up and noticed the entire absence of the wind noise we get in the conventional car. That, together with the lack of wabble and unstable action, is deceptively dangerous when one is first operating the car. One loses the sense of speed because of the absence of noise and wabble and shaking that he gets in conventional cars.

QUESTION:—How does your aerodynamic car compare with the conventional car in regard to front-end stability, shimmy and tramp?

SIR DENNISTOUN:—That is a very difficult question to answer. All I can say is, I never have been in a conventional car that does so well as mine. All those front-end phenomena are due to some mechanical imperfection in the fitting or to some error in design. I think it is true to say that, if the geometry of the steering is correct, if the frame is of sufficient rigidity, if the steering connections are well fitted and well made, one should not get any of those defects mentioned.

Fairing the Under Side Unnecessary

QUESTION:—Do you believe in fairing the under side of the car, or that this is important?

SIR DENNISTOUN:—No, I do not believe that it is. We did it in the first cars, and the undershield fairing weighed 80 lb. and cost a certain sum of money; but tests we carried out showed that the air flow within an inch of the bottom of the car was not sufficient to justify covering in the car as a whole. In this type of car, the underneath part is flush and we have no projections beyond the frame level. I think that fairing the under side is an unnecessary addition to the weight and expense.

QUESTION:—Are your cars built with independent springing, or do they have axles?

SIR DENNISTOUN:—All the cars we have built have independent springing of all four wheels.

QUESTION:—How about rear vision?

SIR DENNISTOUN:—Rear vision is one of the problems with which we have had considerable difficulty. The back view from the present car is not as good as I should like, but the modifications that are necessary are easy to make, are relatively insignificant and, with a little more care in designing the rear end, could easily have been incorporated.

CARL B. FRITSCHE[3]:—I take considerable pride in this meeting because I had something to do with Sir Dennistoun Burney's coming over here. I was his guest in London last June and rode in the car which was bought by the Prince of Wales. I was so much impressed with it that I told Edward P. Warner, Past-President of the Society, and Mr. Kettering and several others about it. As a result, the idea developed that Sir Dennistoun should be invited to come over and address the Society.

This may prove to be an historic meeting. If it does, I shall be very proud, as a fellow airship designer, that it took an airship man from England to come over and tell our American engineers what to do to improve automobile efficiency, how to do it and why.

Blunt Nose and Tapered Tail Unessential

HERBERT G. WINTER[4]:—Sir Dennistoun is to be congratulated for his most interesting paper and the pioneering he has done on this particular type of vehicle.

Certain phases should, I believe, be discussed from the manufacturer's viewpoint. All the streamlined cars that have been discussed to date have had a seating capacity for at least five persons. Admitting that this car could take the place of the sedan models, what about the ever-popular coupés and roadsters? I do not be-

[3] M.S.A.E.—President, Aircraft Development Corp., Detroit.
[4] Consultant, Detroit.

lieve that this design can be adapted to the shorter body styles. Nearly every manufacturer makes a light delivery car on one or more chassis; so, even if the public could be educated to this one model, the engine-in-front design would have to be retained for the commercial vehicles.

Sir Dennistoun seems to be much more interested in the rear-engine possibilities than in producing a car of low air resistance. He stated that the outline of the car was determined solely from aerodynamic considerations. Certain of these fundamentals are not necessarily correct. He listed three general characteristics which he said that wind-tunnel tests show a streamline body must possess.

The word "streamline" pertains to the fluid flow. A body immersed in and moving through a fluid may or may not have a blunt nose and pointed tail, yet, if the laws of streamline flow are adhered to, the flow will be smooth and non-turbulent. By that I mean that the shape may be such that it gives this result or we may obtain it by mechanical means.

Intensive study both here and abroad has produced shapes that do not conform with the blunt-nose theory and yet whose resistance is the same or even less. Having the maximum ordinate at 30 per cent of the length is believed to be correct for least drag on shapes such as wing sections. For bodies of revolution, such as airships, the best position is nearer 45 per cent of the length, and we have even gone so far as to have this maximum cross-section nearer the rear end than the front, and its drag has proved even less. An automobile is not an airfoil nor is it a body of revolution; it is somewhere in between, and I should say it should be considered as being more nearly like the latter. Does this not apply to the design of the present cars, in which we want the greatest height and width near the rear?

Tests have also been run on blunt-nose sections as well as on those having the maximum ordinate at 50 per cent of the length to determine their relative merits when the direction of wind is not parallel with the axis of the model. The symmetrical sections showed the lower drag characteristics over a considerable angle of yaw range.

Sides Should Be Streamlined Too

I believe that in the Burney car the profile has received considerably more attention than the plan form. The sides are too flat and the roof radius too sharp for good aerodynamic principles. Few realize the importance of generous radii and curves. The substitution of curved for flat sides very sharply reduces the effect of yaw on resistance. The importance of flat sides is shown by Wieselsberger[5], who made tests of objects of round and square cross-section, but otherwise similar, at various angles of yaw. With the circular cross-section, a 10-deg. angle from the position of minimum drag increased the drag 33 per cent, whereas, with the square section, the increase was 235 per cent. This test was on objects without any appendages, but it shows clearly the respect we should have for curves. Because of the tremendous amount of "fin area," I wonder what the performance of this car is in a high cross wind.

The great area of the top and its downwardly sweeping slope undoubtedly give a downward momentum to the air, and, if it does, there is some amount of lift. This lift brings into the problem another type of drag called "induced drag," which varies as the square of the lift and inversely as the ratio of width to length. I believe it should amount to considerable proportions. It may be seen that, if this vertical air force is either up or down (as it might be used to hold the car on the road), the induced drag is still there, as it depends on the square of the lift, which must always be a positive number.

From my studies of the subject I believe that the present type of motor-car can be designed so that the resistance is comparable with that of Sir Dennistoun's. The theory of the blunt-nose form is responsible for the opinion that the present cars are running backward, aerodynamically speaking.

The decrease in drag on Sir Dennistoun's creation is due primarily to the decrease in turbulent regions around the front end, the shielding of the rear tires, and the pointed rear end. The general appearance of the front is not so far removed from that of the present automobile, which could very easily be so modified. I appreciate that to some extent the requirements of the passengers dictated this design, but will not that be the case in every such development?

Because of the ground effect I believe more attention should be given to the plan form and less to the profile. We can do little more than cover the under side of the chassis to shield it from the ground flow; so, by streamling the top we are only accomplishing about one-half what we could do should we better the sides. Making the body wider affords a very good means of handling the spare-tire problem. Considerable time should be spent on this, as the popularity of the large-section tire may put an end to its present disposition, and the drag of the spare tire on the outside is certainly appreciable.

I should like to know what the ratio of mileage of the front and rear tires may be on the Burney car.

Author Answers Written Criticism

SIR DENNISTOUN:—I shall answer Mr. Winter's criticisms in the order in which they are made:

(1) The design has been adapted to both the coupé type and the roadster. In the coupé model the "dickey" seat is inside the wheelbase and can be either open or under cover; in the roadster model, the conventional open-car type is followed. As regards the light delivery car, a model designed to open on the side instead of at the rear can be satisfactorily developed.

(2) I agree that in airfoil sections the maximum ordinate should be about 30 per cent of the length from the forward end, and this confirms my contention that the maximum ordinate in the car should be in the same approximate position. With regard to airship models, neither my investigations nor those of the National Physical Laboratory in England agree with Mr. Winter's findings that a lower resistance can be obtained when the maximum ordinate is abaft the center of the vessel. As a matter of fact, I had a series of model tests made especially to study the effect of moving the maximum ordinate aft in the R-100 design, as, for reasons connected with the installation of the engine, I was anxious to have the center of buoyancy farther aft. I had, however, to give up the idea owing to the considerable increase in resistance resulting from moving the maximum ordinate farther from the bow of the vessel than about one-third of the total length.

Practical Considerations Determine Body Form

(3) In the first model the sides were more curved and the roof radius was greater than in later models; in fact, each successive model has had the curve of the sides and the roof radius reduced. In the first case the determining factor was the vertical movement of the windows, and, in the second case, the larger the roof radius is, the more restricted is the view of the passengers.

[5] See National Advisory Committee for Aeronautics Technical Memorandum No. 267.

At a later date, when curved safety glass can be obtained at a commercial price, no doubt these questions can be further considered. I feel, however, that my existing proposals are sufficiently unpopular with the production engineers and thought it better to "let sleeping dogs lie."

(4) The lift at speeds up to 100 m.p.h. is not important. At 60 m.p.h. the total lift on the car is approximately 100 lb. and the induced drag probably is less than 15 lb. The former figure is from model tests and the latter figure estimated.

(5) I cannot agree that a better effect can be obtained by sacrificing passenger and luggage accommodations to a better plan form. After all, the main purpose of the car is to carry passengers in comfort with ample luggage space, and only after this has been done can streamlining considerations determine the resulting shape.

(6) Neither can I agree to the suggestion that the large-section tire will entail modifications to the present method of storage, as I think the large-section tire will gradually be replaced by smaller-section and straight-walled tires. If cruising speeds are raised to 100 m.p.h., I think the danger of a front-wheel burst with the large-section balloon tire will be realized by the public. In all our cars we use a type called in England the "heavy-duty light-lorry tire," with a front-tire pressure of 25 lb. and a rear-tire pressure of 45 lb. per sq. in.

(7) I would answer Mr. Winter's final criticism by asking him this question: Can he show any proof, by wind-tunnel or full-scale test, that, with a given maximum width and maximum over-all length of car, it is possible to obtain as much body space for a given resistance by any shape other than a blunt-nose and pointed-tail layout?

Rearward Center of Gravity Should Increase Sideslip Tendency

MAURICE OLLEY[6]:—Sir Dennistoun stresses riding quality rather than streamlining. I think this is correct perspective, since a lack of streamlining can be compensated by more power, but there is no substitute for a good ride except to stay at home.

We all know that riding quality goes deeper than springs or shock-absorbers and involves the mass distribution, or K^2/AB ratio, of the car itself. But I think that our present experience does not point to great increase of K^2/AB as desirable for steering; rather, the reverse. In straightening up after a curve, an angular retardation must be exerted on the car to stop its rotation about the center of gravity. This retardation seems to be greater as the angular momentum of the car is greater.

In the case of a car of 12-ft. wheelbase and 5640-lb. weight, having a radius of gyration squared of 22.8 ft.^{2}, traveling at 60 m.p.h. in a circle of 240-ft. radius (which is about the limit) and straightened up in 22 ft., the additional sideslip effect on the tires is 490 lb. And this is in a direction to skid the rear tires. If on this car K^2 is made equal to AB, then this sideslip force is increased to 770 lb.

If, in addition, the center of gravity is well toward the rear of the car, the sideslip tendency, from my analysis, is slightly worse. We all know this effect on trucks with a heavy, overhung load, or on passenger-cars with exceptionally large and heavy trunks.

A matter that is not referred to by the author is that the moment of inertia horizontally is likely to be much larger than the moment of inertia involved in riding, because of the addition of the unsprung masses; so that probably a K^2/AB ratio of about 0.75 in the horizontal plane is not unusual with the average passenger load, even on fairly large cars.

Experience shows that, for winter conditions in the United States, a great increase of horizontal moment of inertia is undesirable for roadability and steering. An obvious improvement is to decrease unsprung weight to the utmost so as to improve the ride without increasing skidding.

In addition to the foregoing objection to a high K^2, a further objection to a center of gravity considerably back of the center is that the center of wind pressure is likely to be ahead of the center of gravity when the car swerves. This gives an additional tendency to skid the rear wheels.

Finally, when the driver sits forward of the mass center, angular accelerations imparted to the car have a tendency to "leave him behind," thus tending to throw the car into a sharper curve. This tendency is very noticeable on some "short-nosed" European cars that have high-geared steering.

Skidding Tendency Reduced, Not Increased

SIR DENNISTOUN:—In reply to Mr. Olley, I must say at once that I think there must be some misunderstanding in regard to the basis of discussion that he has selected, as it seems to me that, on going out of the turn, an increased longitudinal moment of inertia must, in fact, reduce the film tension between the tire and the road and thus reduce any tendency to skid.

Surely, if we assume that the car is moving uniformly in a curved path, the effect of moving the front wheels to steer the car toward the direction in which the centrifugal force is acting on the car as a whole will be to reduce the shearing reaction. At the same time, to stop the rotation of the car about its vertical axis is equivalent, so far as the film tension between the tire and the road is concerned, to applying a force in the opposite direction. The magnitude of this force is dependent upon the rate of change of angular velocity and the magnitude of the longitudinal moment of inertia. The final result upon the shearing reaction between the tire and the road is the difference, not the sum, of these two forces.

In regard to the other points raised, I agree that, if the longitudinal moment of inertia is increased without approaching the value $AB = K^2$, then roadability and steering may be adversely affected, but the converse also is true, and if AB does equal K^2, then, within the limits of a practical car, I think it will be found that the roadability is better. For this reason I think that too much attention should not be paid to results of experience with standard cars having large loads behind the axles unless the result is corrected for the evil effect of the secondary reaction caused by the center of percussion and the center of rotation failing to coincide with the axles.

With regard to wind pressure, I can only say that experienced drivers have, after driving the car at high speed in a side wind, stated that in their opinion the wind gusts affect the car less than would be the case in an orthodox car. Similarly in regard to the position of the driver, I have never had any complaint on the score of increased angular acceleration upon the driver. The opinion usually expressed is that, contrary to expectation, one forgets he is not driving a two-seater.

[6] M.S.A.E.—Engineer, special problems, Cadillac Motor Car Co., Detroit.

Characteristics of Alloyed Cast-Iron

National Metal Congress Paper

By F. W. Shipley[1]

INCREASED quality, which is reflected through higher valve-seat hardness and improved microstructure, can be obtained by additions of nickel and chromium to automobile-cylinder iron. Different combinations of these alloys were used, and it was found that a ratio of three parts of nickel to one of chromium gives the greatest improvement in structure in conjunction with maximum hardness. The effect of prolonged heating on three representative plain irons, as well as on three nickel-chromium-alloyed irons of the same base composition, is also shown. A marked difference is revealed in these cases in favor of alloyed irons. A method is given of producing chilled roller wheels by additions of chromium in the ladle instead of using special cupola charges. This is capable of better control and results in a superior product.

PROGRESSIVELY increasing demands of industry for higher quality, improved structure and better wearing properties mark the history of the development of iron for internal-combustion engines; because the modern trend is toward smaller but more powerful engines, higher compression, higher speeds, more cylinders per block and increased combustion temperatures. These requirements having exhausted the ordinary resources of the production foundry, it was natural to turn to other available means for improving cast irons. The use of alloying elements was a consequence.

The research work described in the present paper was conducted to determine some of the qualities which could be obtained through the use of alloys. As each of the problems was separate and distinct, they are given separately. The author wishes to point out that it has not been his purpose to omit any one alloy from this work, but lack of time has limited the investigation to the alloys that have come into more general use in the last decade.

HARDNESS AND STRUCTURE OF AUTOMOBILE CYLINDERS

Because of the difficulties encountered from the wearing of valve seats of automobile engines and uneven wear of the cylinder bore, an attempt was made to increase the hardness and density of the structure, through the use of alloys, beyond the point which had previously been considered safe for machineability. Earlier attempts to accomplish this through lower silicon content and increased steel content had resulted only in machining difficulties due to white or mottled sections in thin parts of the castings.

In an experimental study of this problem, five six-cylinder engine blocks each were poured from ladles containing compositions Nos. 1 to 5 of Table 1. It is to be noticed that the silicon content, which was 2.34 per cent in the regular iron, No. 5, was lowered to approximately 2.10 per cent in those charges to which the alloys were to be added.

The purpose of this investigation was to study the hardness and chilling effect obtained by increasing the chromium content in increments of 0.10 per cent while the nickel content remained the same. This would determine just what ratio of nickel to chromium would be necessary to prevent machining difficulties. The theoretical mixture, however, was not obtained in the case of mixture No. 2. The physical values obtained from test bars which were poured from the same ladles are given also in Table 1.

TABLE 1—ANALYSIS AND STRENGTH OF SIX-CYLINDER CASTINGS

No. of Mixture	1	2	3	4	5
Mixture, per cent					
Pig Iron	35	35	35	35	35
Scrap Iron	50	50	50	50	50
Steel	15	15	15	15	15
Analysis, per cent					
Total Carbon	3.45	3.32	3.43	3.34	3.30
Silicon	2.05	2.05	2.11	2.07	2.34
Phosphorus	0.180	0.184	0.185	0.190	0.190
Sulphur	0.095	0.096	0.095	0.094	0.090
Manganese	0.60	0.61	0.63	0.62	0.64
Nickel	0.53	0.41	0.51	0.49	0.05
Chromium	0.14	0.15	0.25	0.37	0.09
Deflection in 12 In., in.	0.130	0.119	0.150	0.122	0.131
Ultimate Transverse Stress, lb.	3,025	3,120	3,560	3,650	3,100
Tensile Strength, lb. per sq. in.	28,400	29,000	30,100	35,270	29,660

Brinell hardness numbers taken at the valve seat of the five cylinders from each mixture are given in the first line of Table 2. One cylinder from each group, selected as the average of the group, was sectioned longitudinally through the bore, and Brinell readings were taken at intervals of approximately 1½ in. from the head-contact face downward. These readings also are included in Table 2.

It is significant that cylinders of mixture No. 1, having 2.05 per cent of silicon, 3.45 per cent of total carbon and a 3:1 ratio of nickel to chromium, gave a variation of 13 points in Brinell hardness. Mixture No. 2, with practically the same base but a 2.75:1 nickel-chromium ratio, showed a variation of 20 points in Brinell hardness. Mixture No. 3, having virtually the same analysis as No. 1 except that the nickel-chromium ratio is 2:1, gave a difference of 21 points in Brinell

TABLE 2—BRINELL HARDNESS NUMBERS OF SIX-CYLINDER CASTINGS

No. of Mixture	1	2	3	4	5
Averages of Five Castings from Each Mix	163	171	178	189	162
Readings from Sectioned Cylinders					
At Head	167	184	198	227	179
At Approximately 1½-In. Intervals below Head	177	177	187	190	143
	170	170	198	198	141
	164	170	184	194	141
	177	177	181	196	137
	174	178	202	198	163
	177	190	184	221	181
Averages from Sectioned Cylinders	172	178	191	203	157

[1] Foundry metallurgist, Caterpillar Tractor Co., Peoria, Ill. The author acknowledges the assistance given by M. J. Gregory, factory manager of the foundry division; and of G. C. Riegel, chief metallurgist, for taking part of the photomicrographs. These men also are with the Caterpillar Tractor Co.

PHOTOMICROGRAPHS SHOWING A SPATTERING OF FREE CARBIDE IN A NORMAL FINE-GRAINED MATRIX

Fig. 1—Mixture No. 1; Magnification, 150

Fig. 2—Mixture No. 1; Magnification, 500

Fig. 3—Mixture No. 2; Magnification, 150

Fig. 4—Mixture No. 2; Magnification, 500

hardness. Mixture No. 4, which is practically the same as mixture No. 2 but with a 1.25:1 nickel-chromium ratio, gave a difference of 37 points in Brinell hardness. Mixture No. 5, the plain iron, showed the maximum variation of 44 points in hardness. Mixture No. 2 gave a 6-point-higher average hardness than No. 1, but this is due to the 13-points-lower total carbon.

Alloying Aids Uniformity

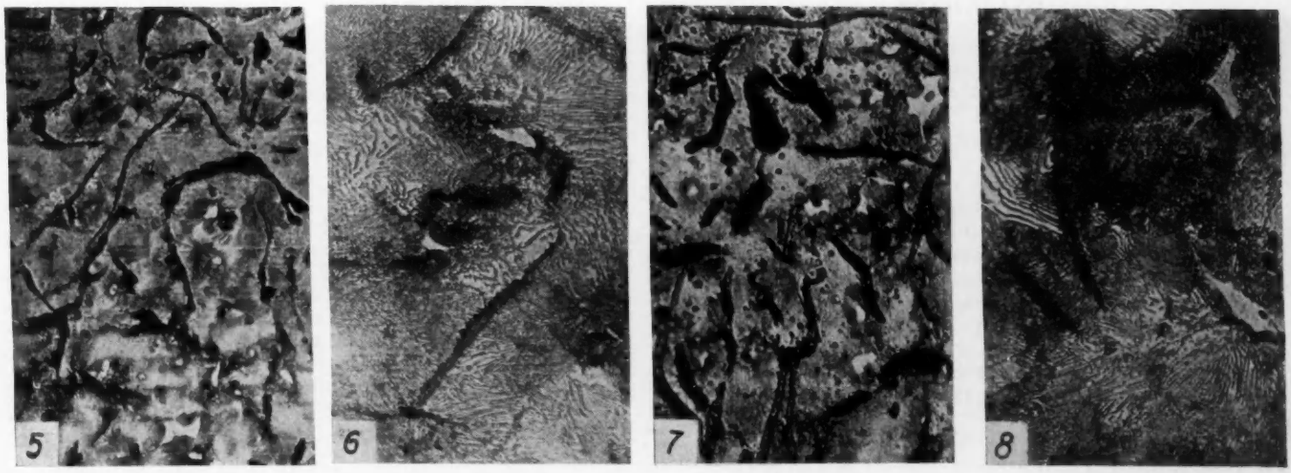
The hardness is comparatively uniform in each lot of alloyed-iron cylinders, as well as throughout the bore of the sectioned cylinder. A decrease in hardness occurred at the junction of the water-jacket wall with the cylinder wall in each case, but this difference was less pronounced in the case of the alloyed irons. One might infer that mixture No. 4 would be ideal from a hardness standpoint; however, mixture No. 1 showed the least variation. This is usually true of the 3:1 nickel-chromium ratio.

The problem then seems to be one of improving mixture No. 4 so that a uniformly high degree of hardness will result. This can be done by raising the nickel content to approximately 1 per cent, thus obtaining an ideal iron for heavy-duty cylinders.

Figs. 1 to 10 illustrate the structures prevailing in the cylinder-casting specimens examined. Details of their structures are described in the captions.

Mixture No. 2 is the best soft iron of the lot. It consists of a pearlitic matrix, just entering into the sorbitic stage in places, with a uniform distribution of small carbide particles in a field of close-grained graphite. The addition of chromium in mixture No. 3 has hardened the matrix somewhat by moving more of it from the pearlitic into the sorbitic stage and also has increased the size of the carbide particles. However, the latter effect is no farther advanced than that which is encountered in the regular iron, while the hardness of the nickel-chromium iron is 40 to 60 Brinell-hardness units greater.

The regular iron, No. 5, is largely pearlitic. It is studded with small particles of carbide which, in size, are between those found in irons Nos. 3 and 4. It dif-



FLATTER AND MORE VELVETY TONE OF MATRIX, CARBIDES MORE NUMEROUS THAN IN MIXTURES NOS. 1 AND 2

Fig. 5—Mixture No. 3; Magnification, 150

Fig. 6—Mixture No. 3; Magnification, 500

INCREASED HARDNESS RESULTS FROM AN INCREASE IN SORBITIC AREAS AND FINE CARBIDES

Fig. 7—Mixture No. 4; Magnification, 150

Fig. 8—Mixture No. 4; Magnification, 500

BASE MIXTURE NO. 5 CONTAINS MORE FREE FERRITE THAN NO. 1, BECAUSE OF HIGHER SILICON CONTENT

Fig. 9—Magnification, 150

Fig. 10—Magnification, 500. Circles Enclose Free-Ferrite and Triangle Free-Carbide Areas

fers from the special irons in the fact that its matrix is expelling free ferrite, undoubtedly on account of the higher silicon content, and also tending to concentrate the carbide particles into knots which develop into hard spots. The presence of free ferrite and free carbides indicates that this is an unsafe structure, inclined toward segregation and a breaking down under heat into soft spots or hard spots, with a resultant lack of uniformity in hardness.

This experiment indicates that much improvement in the Brinell hardness and structures of cast iron can be made by the addition of nickel and chromium, starting at a point above 0.25 per cent chromium and maintaining the nickel-chromium ratio at approximately 3:1. For each 0.10-per-cent increase in chromium above 0.25 per cent, the Brinell hardness number in a given section will increase approximately 10 points above that of the base iron.

STRENGTH AND HARDNESS OF TRACTOR CYLINDERS

As a result of the experience gained in the first investigation, several large separately cast tractor cylinders and the usual test-bars were poured from a ladle to which had been added sufficient chromium and nickel to give theoretical contents of 0.35 per cent of chromium and 1.00 per cent of nickel. These were compared with several other cylinders cast on the same day from the same base mixture of iron but from a different ladle. Sections were cut longitudinally through the bore and Brinell readings were taken at four points equally spaced along the full length of the bore. Table 3 shows these readings, as well as the analysis of the cylinders.

It is readily noted that considerable increase in Brinell hardness number has been obtained in cylinder No. *T*1 through the use of 0.38 per cent of chromium and 1.10 per cent of nickel. This is the identical mixture which the previous investigation indicated would prove ideal for cylinders. Table 4 gives the physical properties of the base iron and the alloyed iron from which the experimental cylinders were poured. Deflection and transverse tests were made on the bars, "as cast," on supports 18 in. apart. A tensile-test specimen (A.S.T.M. for cast iron) was made from one part of each bar after the transverse tests were completed. The structures of these two irons can be compared in Figs. 11 to 14, inclusive. It is noteworthy that the alloy in this case has materially increased the Brinell hardness number of the cylinder as well as the transverse and tensile strength, and this has been done in spite of the fact that the total carbon was 0.12 per cent higher and the silicon 0.15 per cent higher.

TABLE 3—ANALYSIS AND HARDNESS OF INDIVIDUALLY CAST TRACTOR CYLINDERS

Cylinder No.	*T*1	*T*2	*T*3
Analysis, per cent			
Total Carbon	3.49	3.37	3.38
Combined Carbon [a]	0.70	0.57	0.49
Manganese	0.65	0.61	0.62
Phosphorus	0.157	0.158	0.152
Sulphur	0.109	0.138	0.141
Silicon	2.11	1.96	1.93
Nickel	1.10	0.29	0.30
Chromium	0.38	0.03	0.03
Brinell Hardness Numbers			
At Four Points	217	170	187
	196	163	156
	207	156	170
	207	179	185
Average	207	167	174

[a] Sample for combined carbon taken midway between head-contact face and lower junction of water-jacket with barrel.

Results with Cylinder Irons

From the data of these two similar investigations we learn that it is possible to produce practically any desired hardness and structural improvement by properly adjusting the base mixture according to the thickness of metal to be cast, then adding sufficient chromium to raise the Brinell hardness and enough nickel to offset the excessive chilling effect which would result from additions of chromium alone.

Nickel alone, added to any given base iron of the automotive type which is already suitable for a particular casting, will not materially improve the casting except in machining qualities. Either the silicon must be lowered to a point which would be dangerous and nickel added to offset the chilling effect of the low silicon, or chromium must be added and nickel introduced in an approximate ratio of 3 nickel to 1 chromium to offset the difficulties in machining with the addition of chromium alone. The latter method is the more practical of application in the usual production foundry, because of the possibilities of producing many different grades of iron from one base. However, we must not lose sight of the fact that, whatever alloys are used, the base mixture must be as high in quality as is possible to obtain and further improvement made by adding alloys, as alloys added to an inferior grade of iron are only wasted.

TABLE 4—PHYSICAL PROPERTIES OF TRACTOR-CYLINDER IRON

	Base Iron	Alloy
Transverse-Test Specimen on 18-In. Centers		
Deflection, in.		
At 1000 Lb.	0.064	0.074
At 2000 Lb.	0.074	0.190
At Break	0.268	0.290
Transverse Stress, lb.	2,457	2,665
A.S.T.M. Tensile-Test Specimen		
Tensile Strength, lb. per sq. in.	34,600	35,975

EFFECT OF PROLONGED HEATING

The demand for increased speed and higher engine temperatures has created one more problem for the producers; that is, to make an iron which will not de-

crease in hardness when subjected to high temperatures for long periods. To determine which type of iron is best suited to these conditions, six representative types were selected for investigation. Three were plain iron and three others were made by the addition of nickel and chromium to the ladle from the same heats as the plain iron. Table 5 gives the analyses and physical properties of the six irons under investigation, as cast.

The specimens selected for the subsequent heat-treatment were 1¼ in. in diameter and ¾ in. thick, cut from the arbitration bars as cast. Specimens from each iron were heated in the electric furnace for 90 hr., one each at 600, 800, 1000, 1200 and 1300 deg. fahr. Brinell-hardness determinations were made after the first hour of heating, after which the specimens were returned to the furnace to complete the full 90-hr. drawing period. Upon conclusion of the 90-hr. heating, both Brinell-hardness-number and combined-carbon determinations were made on each set. The combined-carbon determinations were secured in duplicate on all the specimens. The average results are given in Table 6.

TABLE 5—IRON TESTS FOR EFFECT OF HEAT

	Silicon Content					
	Low		Medium		High	
	Plain	Alloy	Plain	Alloy	Plain	Alloy
Mixture No.	*H*1	*H*2	*H*3	*H*4	*H*5	*H*6
Analysis, per cent						
Total Carbon	3.12	3.10	3.10	3.15	3.33	3.35
Combined Carbon	1.09	1.05	0.79	0.90	0.67	0.82
Silicon	1.08	1.13	1.69	1.76	2.34	2.32
Nickel	...	1.21	...	1.13	...	0.86
Chromium	...	0.39	...	0.45	...	0.41
Deflection in 12 In., in.	0.125	0.107	0.138	0.159	0.129	0.123
Ultimate Transverse Stress, lb.	4,030	4,130	4,160	5,030	3,420	3,715
Tensile Strength, lb. per sq. in.	29,050	31,550	34,400	44,450	29,640	34,580
Brinell Hardness Number	241	286	228	262	183	217

The combined carbon of the low-silicon nickel-chromium iron shows considerable stability when this iron is heated for long periods up to temperatures as high as 1300 deg. fahr., while that of the higher-silicon-alloy irons held up better than any of the three plain irons. Of the three regular irons, the low-silicon is much the best, having retained its combined carbon up to 1000 deg., at which point the higher-silicon types have lost nearly half of their combined carbon. Therefore it appears that, at temperatures below the critical of plain iron, the stability of the combined carbon is a function of the silicon content.

TABLE 6—PERCENTAGE OF COMBINED CARBON IN IRONS AFTER HEATING FOR 90 HR. AT VARIOUS TEMPERATURES

Mixture No.	*H*1	*H*2	*H*3	*H*4	*H*5	*H*6
As Cast	1.09	1.05	0.79	0.90	0.67	0.82
Heating Temperatures, deg. fahr.						
600	1.14	1.17	0.90	1.03	0.65	0.79
800	1.20	1.09	0.87	0.97	0.59	0.76
1000	1.22	1.13	0.48	0.98	0.42	0.72
1200	0.09	0.86	0.05	0.34	0.05	0.28
1300	0.05	0.70	0.03	0.25	0.02	0.20

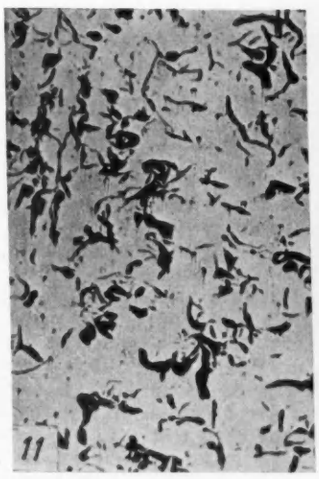
Probably the most striking feature concerning this series of irons is that the combined carbon of each iron remained at a fairly high level at 1000 deg. and that it required the 1200-deg. 90-hr. draw to lower it to any serious extent. Another very interesting point is the general increase of combined carbon of the two lower-silicon irons with the drawing temperatures up to 800 deg. and in some cases up to 1000 deg. No satisfactory explanation can be given for this peculiar trend of the combined carbon in the comparatively lower temperature ranges. However, the 90-hr. draws at 1000 to 1300 deg. have an effect upon the combined carbon which indicates a marked advantage for the alloyed irons.

The Brinell-hardness-number determinations made on the same specimens are listed in Table 7. These in general agree with the combined carbon shown at the same temperatures, except that no increase is noted, such as there was in Table 6.

Only two of the six irons were studied microscopically, to avoid repetition. Those selected were the

TABLE 7—BRINELL HARDNESS NUMBERS OF IRONS AFTER HEATING FOR 90 HR. AT VARIOUS TEMPERATURES

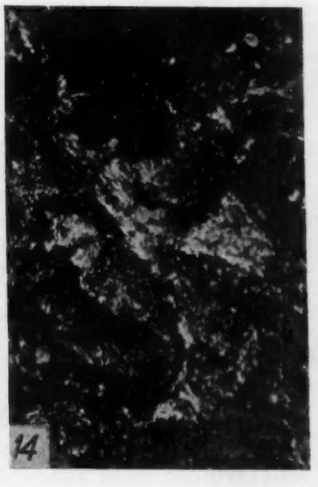
Mixture No.	*H*1	*H*2	*H*3	*H*4	*H*5	*H*6
As Cast	241	286	228	262	183	217
Heating Temperatures, deg. fahr.						
600	223	260	228	262	183	217
800	223	262	223	262	173	212
1000	228	255	203	255	160	194
1200	107	179	112	135	114	147
1300	109	174	110	140	108	140



BASE IRON NO. *T*3, SHOWING FINELY DIVIDED GRAPHITE

Fig. 11—Unetched; Magnification, 100

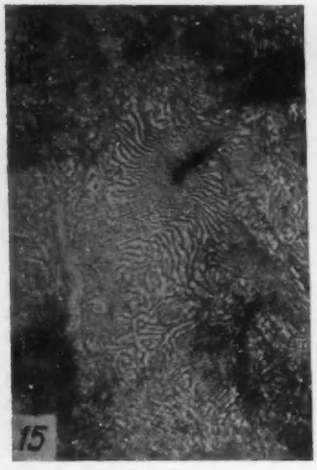
Fig. 12—Etched; Magnification, 500

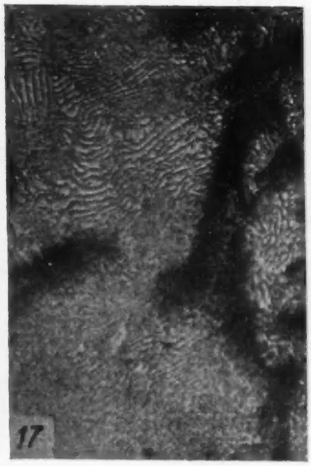


ALLOY NO. *T*1, GRAPHITE COARSER THAN IN NO. *T*3, BECAUSE OF HIGHER TOTAL CARBON

Fig. 13—Unetched; Magnification, 100

Fig. 14—Etched, Magnification, 500





FIGS. 15 TO 20—EFFECT OF HEATING IRONS FOR 90 HR. AT TWO TEMPERATURES. MAGNIFICATION, 500 TIMES

Fig. 15—Mixture No. *H*1, as Cast

Fig. 16—Mixture No. *H*4, as Cast

Fig. 17—Mixture No. *H*1, after Drawing at 800 Deg. Fahr.

Fig. 18—Mixture No. *H*4, after Drawing at 800 Deg. Fahr.

plain low-silicon and the medium-silicon nickel-chromium iron. It was felt that these two should demonstrate the advantages or disadvantages of the alloyed irons, with the plain iron placed in the most favorable position because of its low silicon content. It is evident from the analyses that photomicrographs of the others would not have shown any structures distinctively different from those which are shown. Photomicrographs were made of these two irons after each of the following treatments: (*a*) as cast, (*b*) drawn at 800 deg. fahr. for 90 hr., and (*c*) drawn at 1300 deg. for 90 hr. These are shown in Figs. 15 to 20, inclusive.

The matrix of the plain low-silicon-iron mixture No. *H*1, in the "as cast" condition, is seen in Fig. 15 to consist mainly of pearlite with little if any free carbide. The medium-silicon nickel-chromium iron, mixture No. *H*4 (Fig. 16), has a pearlitic-sorbitic matrix containing a few free carbides but no free ferrite. Figs. 17 and 18 show the structure of these two irons after drawing for 90 hr. at 800 deg. It is evident that little or no change was produced by this treatment.

Drawing the irons at 1300 deg. fahr. for 90 hr. produces the structures shown in Figs. 19 and 20. It is seen that the matrix of the plain low-silicon iron, mixture No. *H*1, consists of nearly all free ferrite with only remnants of pearlite clinging to the large graphite flakes. This same treatment on the medium-silicon nickel-chromium iron, mixture No. *H*4, produces a matrix which, although largely ferritic, still shows an appreciable percentage of pearlite scattered throughout.

An outstanding feature of these data is the confirmation of the fact that silicon is the most important element to be considered in heat-resistant irons. Furthermore, the alloy iron was in each case superior to the plain iron of the same or even lower silicon content.

Perhaps the relation between high Brinell hardness number and heat-resistant properties is most important in parts such as Diesel-engine cylinder-liners, brake drums, engine cylinders and cylinder heads. High hardness, if secured by producing a fine pearlitic-sorbitic matrix, is considered to be indicative of good resistance to wear. However, if the high hardness is produced by free carbides, good wear resistance does not necessarily follow and the carbides may actually be harmful, as in the case of brake drums, where it is thought that free carbides tend to tear the brake lining. If, in conjunction with a high pearlitic-sorbitic hardness, the iron possesses good heat-resistant properties, it is an ideal material for the applications mentioned.

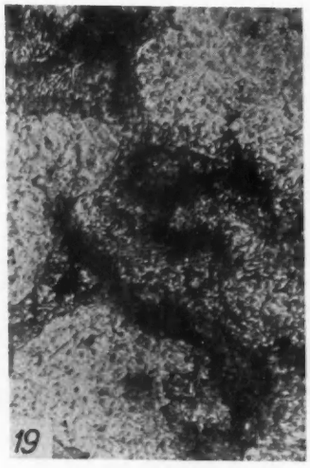


Fig. 19—Mixture No. *H*1, after Drawing at 1300 Deg. Fahr.

Fig. 20—Mixture No. *H*4, after Drawing at 1300 Deg. Fahr.

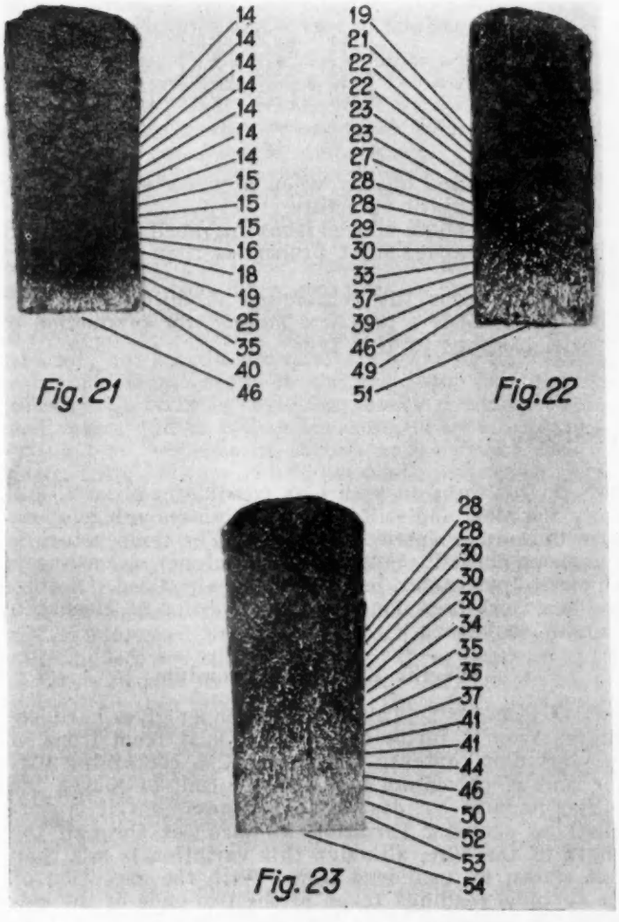
FERROCHROMIUM FOR CHILLED ROLLER CASTINGS

Rollers, or idlers, support the moving track of track-laying-type tractors. They are subjected to excessive wear, and it is therefore necessary that the depth of chill on the face of the casting be maintained within narrow limits. These castings are poured in a permanent mold, and experience has proved that a definite relation exists between the chill depth on a test piece poured against a chill and that which is produced in the casting poured from the same ladle. For this reason a chilled test-piece is poured from each ladle used for such castings, and the castings are accepted or rejected on the depth of chill found in the chill test.

Formerly the practice was to make special cupola charges for these castings by lowering the silicon content and increasing the percentage of steel. Since the rollers are of several different sizes, varying in weight from 25 to 125 lb., and all require the same chill depth

on the tread, it was necessary to make a special mixture for each size to compensate for the difference in weight and section of the castings. These special charges were introduced either at the beginning of the heat or at such a time that they would melt down during the lunch hour and be poured while the remainder of the foundry was shut down. Since the tonnage of these castings is small and accurate control is difficult to obtain, this method was a source of much inconvenience in an otherwise continuous cycle of melting. It was only natural, therefore, that we should attempt to find some method by which we could alloy the regular grade of iron in the ladle and pour these special castings at any time during the day. Since chromium is a powerful agent against graphitization, it was selected as the alloy to be used.

The test procedure was as follows: From a 3-ton mixing ladle of regular iron, a set of arbitration bars and a chill-test specimen were poured and designated as *A*. To 1 ton of iron from this same ladle, 15 lb. of 70-per-cent ferrochromium was added and a similar set of castings poured and designated as *B*. To another ton of iron from the same large ladle, 25 lb. of ferrochromium was added and another set of castings poured and marked *C*.



HARDNESS READING AT THE CENTER OF POLISHED SECTIONS OF STANDARD CHILL-TEST SPECIMENS AT 1/16-IN. INTERVALS, ROCKWELL C SCALE

Fig. 21—Iron *A*, Chilled 1/8 In. Deep

Fig. 22—Iron *B*, Chilled 5/16 In. Deep

Fig. 23—Iron *C*, Chilled 9/16 In. Deep

TABLE 8—ANALYSIS AND STRENGTH OF IRONS FOR ROLLERS

Iron	*A*	*B*	*C*
Analysis, per cent			
Total Carbon	3.43	3.40	3.44
Combined Carbon	0.65	0.79	0.91
Silicon	2.04	2.02	2.00
Manganese	0.63	0.62	0.61
Phosphorus	0.160	0.163	0.159
Sulphur	0.120	0.125	0.121
Chromium	0.05	0.51	0.87
Nickel	0.18	0.19	0.20
Deflection in 18 In., in.			
At 1000 Lb.	0.064	0.057	0.049
At 2000 Lb.	0.185	0.152	0.129
At Break	0.268	0.234	0.216
Ultimate Transverse Stress, lb.	2,450	2,600	2,625
Tensile Strength, lb. per sq. in.	34,600	40,200	41,450

Flexible Method Yields Good Results

Analyses of millings taken from the fractured ends of the transverse-test bars and the physical values obtained from the test bars poured from these different grades of iron are given in Table 8.

The chill depth and hardness of chill as determined on the standard chill-test specimens are shown in Figs. 21, 22 and 23. Rockwell C readings 1/16 in. apart were taken in the center of the cross-sections shown, after polishing.

Hardness tests were made on a section through the hub and tread of a typical roller poured with chromium-treated iron. The average hardness on the hub ends before machining was 217, to be compared with 179 for rollers taken from regular production which had been made from the special cupola charges.

As the results of this test proved very favorable, this method of producing these grades of iron was adopted and has been in regular use for some time. In addition to producing a chilled casting of superior quality, it lends itself to simple control in regular production by varying the quantity of ferrochromium that is added in the alloying process inversely as the depth of chill which is obtained from the regular iron at that particular time.

Tables 9 and 10 give, for comparison, values obtained from a number of test bars poured during approximately six months of regular production by the old and the new methods for grades Nos. 1 and 2, respectively.

This experiment affords a good opportunity for studying the effects on combined carbon and physical values which can be obtained by the addition of ferrochromium to cast iron of medium silicon content. The increase in combined carbon was notable and almost directly proportional to the quantity of chromium added, while at the same time a corresponding decrease in deflection is to be observed. The action of ferrochromium is directly opposite to that of nickel.

It is also of interest to note that chromium-alloyed iron develops greater hardness at the face of the chill, which indicates greater wearing qualities. In addition, greater hardness is shown in the gray section behind the chill; while there is no sudden break in hardness at this point, as there was with iron made by the old method and showing the same chill depth.

The general averages of the tensile tests show that the chromium-treated iron is approximately 6000 lb. per sq. in. stronger than the regular cast iron and averages 4000 lb. per sq. in. stronger than even a lower-silicon iron of higher steel content.

GENERAL SUMMARY

Chromium in iron increases the hardness and strength by combining the carbon and producing a more stable double carbide of iron which crystallizes out with the pearlite, while nickel tends to dissolve this free-cementite-forming pearlite. A combination of the two alloys

TABLE 9—ANALYSES AND PROPERTIES OF NO. 1 GRADE ROLLER IRONS

	Old Method: 30% Pig, 47½% Scrap and 22½% Steel						New Method: 35% Pig, 51½% Scrap and 12½% Steel, Plus Ferrochromium								
	Individual Specimens					Averages	Individual Specimens								Averages
Analysis, per cent															
Total Carbon	3.14	3.47	3.42	3.43	3.25	3.37	3.40	3.35	3.46	3.49	3.43	3.46	3.46	3.40	3.43
Combined Carbon	0.72	0.86	0.77	0.71	0.69	0.75	0.76	0.79	0.90	0.74	0.74	0.74	0.83	0.71	0.78
Silicon	1.92	1.82	1.81	1.89	1.80	1.85	1.96	2.04	1.90	2.01	2.11	1.95	2.02	1.95	1.99
Chromium	0.06	0.13	0.06	0.09	0.14	0.10	0.47	0.36	0.44	0.56	0.61	0.51	0.59	0.35	0.48
Nickel	0.12	0.11	0.08	0.08	0.14	0.10	0.14	0.19	0.34	0.17	0.30	0.10	0.13	0.28	0.21
Chill Depth, in.	7/16	3/8	1/2	5/16	7/16	13/32	3/8	3/8	7/16	3/8	3/8	3/8	3/8	5/16	3/8
Deflection in 18 In., in.															
At 1000 Lb.	0.055	0.069	0.065	0.072	0.060	0.064	0.061	0.060	0.050	0.047	0.040	0.065	0.064	0.061	0.056
At 2000 Lb.	0.157	0.167	0.165	0.204	0.160	0.171	0.162	0.160	0.136	0.141	0.125	0.169	0.157	0.146	0.150
At Break	0.230	0.229	0.239	0.246	0.218	0.232	0.249	0.241	0.221	0.221	0.215	0.252	0.242	0.240	0.235
Ultimate Transverse Stress, lb.	2,425	2,400	2,450	2,275	2,310	2,372	2,560	2,525	2,650	2,640	2,735	2,535	2,610	2,700	2,620
Tensile Strength, lb. per sq. in.	35,900	37,400	37,475	34,750	35,600	36,225	37,700	38,200	41,700	42,000	43,100	39,000	42,500	43,000	40,900

TABLE 10—ANALYSES AND PROPERTIES OF NO. 2 GRADE ROLLER IRONS BY OLD AND NEW METHODS

	Old Method: 10% Mayari, 20% Other Pig, 35% Scrap, 35% Steel						New Method: 35% Pig, 52½% Scrap, 12½% Steel, Plus Ferrochromium				
	Individual Specimens					Averages	Individual Specimens				Averages
Analysis, per cent											
Total Carbon	3.24	3.26	3.49	3.34	3.43	3.35	3.50	3.41	3.55	3.52	3.49
Combined Carbon	0.82	0.79	0.82	0.71	0.79	0.78	1.01	0.74	0.87	1.03	0.91
Silicon	1.85	1.83	1.74	1.48	1.66	1.71	1.82	1.91	2.01	2.17	1.98
Chromium	0.13	0.13	0.12	0.15	0.17	0.14	0.90	0.74	0.88	0.95	0.87
Nickel	0.12	0.10	0.11	0.10	0.13	0.11	0.12	0.50	0.11	0.21	0.24
Chill Depth, in.	7/16	5/8	9/16	3/4	11/16	5/8	11/16	3/4	9/16	5/8	5/8
Deflection in 18 In., in.											
At 1000 Lb.	0.601	0.057	0.062	0.064	0.062	0.061	0.051	0.050	0.050	0.045	0.049
At 2000 Lb	0.166	0.158	0.155	0.162	0.160	0.160	0.313	0.120	0.141	0.124	0.129
At Break	0.240	0.210	0.222	0.235	0.226	0.226	0.191	0.252	0.221	0.200	0.216
Ultimate Transverse Stress, lb.	2,425	2,350	2,300	2,560	2,360	2,400	2,540	2,625	2,660	2,640	2,616
Tensile Strength, lb. per sq. in.	38,300	36,500	38,500	39,725	37,600	38,125	39,200	43,700	42,900	41,400	41,800

in the ratio of approximately 3 nickel to 1 chromium will produce an iron for automotive-engine cylinders which is superior to plain iron with respect to hardness, strength and microscopic structure. The percentage increase of these properties varies almost as the percentage of alloys used.

Increased Brinell hardness is not desirable if accompanied by excessive free cementite, but it is an indication of increased quality when produced by a pearlitic or pearlitic-sorbitic structure.

Nickel-chromium-alloyed irons are much superior with respect to heat-resistant properties than are ordinary irons.

Alloying irons with chromium produces a superior chill and affords a practical method for production of special castings of this type.

THE DISCUSSION

H. H. ASHDOWN[2]:—Cast iron alloyed with nickel and chromium, in the proportions outlined by the author, unquestionably has overcome many of the difficulties previously encountered in engine cylinders under service conditions. Not only does the valve seat give longer life by resisting deformation from hammering, but also "pick-up," which is one of the major difficulties, has been overcome. Machining qualities are more uniform, and the cylinder walls present a smoother wearing surface and give longer life.

I should like to learn from the author whether, in his experience with this alloy, he has noticed any marked difference in the general qualities of the cylinders by varying the casting temperature, and at what temperature he has obtained the best and most consistent results.

The addition of Meehanite to alloy cast iron makes the same relative improvement in physical properties as when added to straight gray iron. Has the author found the physical properties to be further enhanced by such addition?

F. W. SHIPLEY:—We never have done any work with varied casting temperatures, since it is absolutely necessary to get the iron as hot as possible in order to dissolve the alloy and still maintain high enough temperature to pour an intricate casting. The temperature at the spout normally is 2800 deg. or higher, according to an optical pyrometer, before the alloy is added. Neither has any work been done with the addition of Meehanite to alloy cast iron.

Specific Effect of Chromium

C. O. BURGESS[3]:—Table 2 of the paper gives hardness figures from a series of cylinders cast from irons of varying alloy content. Mixture No. 4, containing 0.37 per cent of chromium and 0.49 per cent of nickel, the author finds to be ideal as to hardness; but it is criticized as showing variation in hardness through the length of the bore, although this variation is less than that shown by unalloyed iron. With the exception of the extreme readings taken at the two ends of the cylinder, the variation along the bore is only 8 points; that is, the evenness in hardness in the main section of the bore is equal or superior to that of cylinders cast from any other mixture considered. The hardness at the extreme ends of this cylinder is only 26 and 32 points higher than the average bore hardness of the six cylinders of the same mixture and exceeds the hardness of tractor cylinder No. *T*1, in Table 3, which is particularly

[2] Plant metallurgist, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

[3] Union Carbide & Carbon Research Laboratories, Long Island City, N. Y.

recommended by the author, by only 10 points. Cast iron hardened by chromium additions—up to at least the maximum hardness of 227 Brinell, exhibited by cylinder No. 4—does not suffer any serious loss in machining qualities. Mixture No. 4 also possesses the greatest strength of any of the cast irons of this series, the strength of which increases with the increase in chromium content.

It is evident from this paper, as from previous investigations, that chromium is a most active agent in preventing deterioration and consequent wear of cylinders under the effect of heat or high combustion temperatures.

In view of the results reported by Mr. Shipley and recent work by Theodore Klingenstein[4], in which the latter finds that chromium is all important when considering wear or heat resistance, it is evident that much greater stress should be placed on the chromium content of cast iron. Excellent results evidently can be obtained by the use of chromium, alone or in conjunction with small percentages of other alloying agents.

MR. SHIPLEY:—Our experience with respect to cylinders has been that any addition of chromium which is not offset by additional silicon or nickel will cause considerable difficulty in machining at the usual production rates.

Results of Control of Carbon

V. A. CROSBY[5]:—Mr. Shipley's paper covers the subject of chromium-nickel cast iron very well; but it is regrettable that molybdenum and vanadium were not considered also, since they are most assuredly alloying elements of considerable importance. Molybdenum, with nickel, gives remarkable physical properties, although its cost is somewhat against it.

I do not agree that an iron having a total carbon content of 3.30 per cent can be labelled the last word in cupola practice; our experience has indicated that percentages above that figure are unsatisfactory for automobile cylinders. A great improvement in structure can be made by lowering the total carbon to 3.00 to 3.10 per cent; but I would not advise a lower figure, because of trouble from cracks in the castings. We have no difficulty in securing cylinder blocks showing Brinell readings of 190 to 202 in the bore, using a plain iron having 3.10 per cent of carbon and 1.90 per cent of silicon. An addition of 0.25 per cent of chromium gave a reading of 228 in the bore, with increased difficulty in machining.

Use of chromium and nickel in cast iron has been well demonstrated. Little argument can be offered against it except the ever-present question as to whether it is worth its cost. I agree that the Brinell reading will be increased 10 points for each 10 points of chromium added, and that from two to three times as much nickel is needed to break down the very stable double carbides of iron and chromium. The microphotographs show that a great deal of iron-chromium carbides exists, even with the addition of nickel. Breaking down into pearlite and ferrite depends directly upon the temperature of the iron when the alloy is added and the percentage of nickel and chromium added. Hot iron is necessary for the addition of any alloy, especially chromium.

I am of the opinion that chromium should not be added to cylinder-block iron, either alone or in combination, because of the ever-present double carbides which may or may not be broken down into pearlite and ferrite. Remarkable results in strengthening the matrix are being attained by the use of equal parts of nickel and molybdenum, and they do not depend upon the dispersion of the very hard, stable carbides of chromium.

Results in the author's tests of six-cylinder castings can hardly be considered as comparable, because the silicon content was 0.24 per cent lower in the iron to which the alloy was added. The author's statements in regard to the results of the cylinder-block experiments are good.

Experiments with Molybdenum

MR. SHIPLEY:—We have not done enough work with vanadium to be qualified to discuss it, but we have run a few experiments which are of interest with respect to molybdenum. Four alloy cast irons were made from the same ladle of base iron. These were molybdenum, chromium, nickel-molybdenum and nickel-chromium. The analyses and physical properties obtained from test bars of these irons are given in Table 11.

In addition to the improvement in physical properties, which are indicated in Table 11, photomicrographs show that molybdenum has a very strong tendency to break up graphite and distribute it uniformly over the field. The nickel-molybdenum iron was almost ideal in structure in this respect, but of course the cost of an iron of this kind is nearly prohibitive.

I agree with Mr. Crosby that iron containing more than 3.30 per cent of total carbon is not as desirable as one containing less, but I still believe that irons containing 3.00 to 3.10 per cent of total carbon can be further improved by the use of alloys. Mr. Crosby's statement that chromium should not be added to cylinder-block iron is unwarranted, in view of the thousands of chromium-alloyed cylinder-blocks which have proved their value on actual road tests.

TABLE 11—COMPARATIVE TESTS OF VARIOUS ALLOYS

Type	Base Iron	Molyb-denum	Chro-mium	Nickel-Molyb-denum	Nickel-Chro-mium
Analysis, per cent					
Total Carbon	3.30	3.30	3.30	3.30	3.30
Combined Carbon	0.77	0.81	0.76	0.70	0.80
Silicon	2.10	2.10	2.10	2.10	2.10
Manganese	0.62	0.62	0.62	0.62	0.62
Phosphorus	0.160	0.160	0.160	0.160	0.160
Sulphur	0.160	0.160	0.160	0.160	0.160
Chromium	0.05	0.05	0.44	0.05	0.46
Nickel	0.34	0.34	0.34	1.35	1.14
Molybdenum	...	0.31	...	0.37	...
Deflection in 18 In., in.	0.270	0.317	0.300	0.294	0.262
Ultimate Tensile Strength, lb. per sq. in.	34,450	37,900	37,000	42,450	37,350

MR. CROSBY:—Why should we spend money alloying an inferior iron having a carbon content of 3.30 to 3.44 per cent when improved cupola practice will produce a superior iron with a carbon content of 2.95 to 3.15 per cent? Alloying the latter iron would no doubt improve the physical properties, however.

Referring to the number of chromium-alloyed blocks in service, we have made thousands of blocks with a chromium addition of 0.25 per cent, and we hold no brief for chromium because of the double carbides of iron and chromium that segregated in the bores of the cylinder blocks. Much better results are obtained by improving the cupola practice so that a lower carbon content can be obtained and leaving out the chromium.

Practice of a Truck Builder

W. J. DIEDERICHS[6]:—The author is to be congratulated for a clear demonstration of the improvement to be made by the alloying of cast irons and a restatement of these gains and of the proper procedure to be used in their attainment. Of particular significance is the

[4] See *Mitteilungen aus Forschungsanstalten*, April, 1931, p. 80.
[5] Foundry metallurgist, Studebaker Corp., South Bend, Ind.
[6] M.S.A.E.—Metallurgist, The Autocar Co., Ardmore, Pa.

clear-cut, concise summary of the considerations to be borne in mind, which are embodied in his statements regarding the results with cylinder irons.

Tables 8 and 9 and the accompanying text clearly indicate that chromium sharply increases hardness and strength, reduces deflection below that of the plain base iron and increases chill. Therefore it necessarily increases non-uniformity of properties in an intricate casting. Table 4 and the accompanying text, showing the effect of adding nickel to a chromium-bearing iron of a very similar base material, indicates that further addition of nickel increases the deflection beyond that of the plain base iron, and it reduces chill and improves the uniformity of properties throughout an intricate casting.

These results are important in a casting such as a cylinder block, which is subject to differential chilling when it is cast and to differential heating and therefore stressing in service. The nickel-bearing irons show an advantage against subsequent warping and cracking in service and, as the author demonstrates, they hold their hardness better under heat in service.

For its possible value as an addition to the author's data, we give below the analysis which experience has indicated to us is excellent for cylinder blocks:

Constituent	Content, Per Cent Specified	Usual
Total Carbon	3.4 Maximum	3.2 –3.35
Manganese	0.50–0.70	0.60–0.65
Silicon	Open	2.1 –2.25
Phosphorous	0.20 Maximum	0.14–0.16
Sulphur	0.12 Maximum	0.09–0.12
Chromium	0.35–0.60	0.45–0.55
Nickel	1.25 Minimum	1.30–1.45

Blocks of this analysis are annealed at 900 to 950 deg. fahr. to relieve casting stresses and minimize warpage in service. Hardness is held between 190 and 225 Brinell, and the blocks offer no undue machining difficulties. Transverse tests consistently show 3800 to 3900 lb. and 0.11 to 0.12-in. deflection for 1¼-in. bars on 12-in. centers.

The part of the paper concerned with the effect of annealing various cast irons is very interesting but extremely puzzling. We should expect the microscope to show excess carbides in low-silicon plain or alloyed irons such as mixture No. *T*1, but Fig. 15 shows none and the author states that practically none is present. Still, he reports the combined carbon as 1.05 to 1.09 per cent, and this is decidedly beyond eutectoid concentration.

After heating at low temperatures, he reports an increase in combined carbon but no change in structure. Certainly, combined carbon in such quantities should show up as excess carbides, for the eutectoid ratio of cast irons is admittedly lower than 0.9 per cent of carbon. We believe that full-pearlitic matrix in cast irons usually is obtained when combined carbon is between 0.6 and 0.8 per cent. We feel that the combined carbons reported do not agree with the structures shown. Further, unless the cooling rate was retarded, the structures shown for the low-silicon mixtures and possibly the medium-silicon mixtures do not seem to be normal. As stated, we should expect to find excess carbides in the structure.

Effect of Annealing on Combined Carbon

That combined carbon increases upon low-temperature annealing of medium and low-silicon irons is difficult to believe and will require further verification; we know of no other similar observations. Iron carbide, however, is not stable at temperatures below the critical and should break down to ferrite and graphite upon heating, as it evidently does in this case at temperatures above 1000 deg. fahr. There is no obvious reason why it should act otherwise if any change at all occurs at lower temperatures. Since hardness in cast irons is in general directly proportional to the amount of combined carbon present, the author's Brinell data indicate that the combined carbon decreased rather than increased.

We are particularly interested in the change in Brinell hardness obtained upon annealing. These data indicate that any cast iron drops off sharply in hardness when heated for long periods above 1000 deg. fahr., and the drop starts at lower temperatures in commercial mixtures. The author does not report the hardness results obtained after 1 hr. of heating; they no doubt follow the same general trend, possibly showing analogous reductions in hardness at somewhat higher temperature. We should welcome a report of the results obtained.

The present trend in cast irons is to the high-strength type of either the plain-carbon or alloyed variety. Not infrequently, machining difficulties are encountered because of chill or hard spots, both due to excess carbides, and the difficulty is overcome by annealing. Temperatures in the red heat are required to eliminate hard spots and to correct the machining difficulty, and these data indicate that the drop in hardness is excessive. The drop in hardness is due to breakdown of carbides and pearlite and is associated with a reduction in physical properties and wear resistance. We question the advisability of ever annealing a casting to eliminate hard spots—even alloyed irons, the strength of which is better maintained—if strength is of importance in the application. We feel that it is better practice to keep castings a little softer, so that annealing for machinability is not necessary. We believe that cast irons should be annealed only for relief of casting stresses and at temperatures preferably not higher than 900 to 1000 deg. fahr.

MR. SHIPLEY:—The cooling rate in the low-silicon irons was rapid enough to hold the combined carbon slightly above the pearlitic-concentration limit, and therefore the structure does not show excess free carbide. In other words, the structure is not truly pearlitic but slightly sorbitic. The solubility of combined carbon in low-silicon irons is slightly higher than in high-silicon irons.

Automobile Fuel-System Design and Vapor Lock[1]

Annual Meeting Paper

By Oscar C. Bridgeman[2] and Hobart S. White[3]

TEMPERATURE rise in the gasoline as it passes through the fuel system is the important factor in vapor lock that is within the control of the car designer. Gravity and vacuum-tank feed systems are considered briefly, including tests showing that weathering of the gasoline in the vacuum tank consists largely in removal of propane.

Vapor lock in a pump system is most liable to occur on the suction side, because of the difference in pressure. Increasing the capacity of the pump for handling vapor offers little relief. Evidence is presented to show the gain made by locating the fuel line where it is protected from the heat. One example is cited to show the advantages of keeping a large flow of hot engine oil away from the pump. It is advantageous also to locate the pump where it will be cooled by the air entering the engine compartment of the car.

THE FUNCTION of the fuel-feed system in any automobile is to deliver the fuel continuously from the supply tank to the inlet manifold of the engine in the desired amounts. A common cause of failure to perform this function satisfactorily is the occurrence of vapor lock, or boiling of the gasoline, in the fuel-feed system. Vapor lock may occur as the result of poor design and installation of the fuel system, of excessive fuel vapor pressure, or of adverse atmospheric conditions. Whereas it is not possible to control atmospheric conditions, fuel vapor pressure can be controlled within limits by the petroleum refiner, and the design and installation of fuel-feed systems can be modified within limits by the automotive engineer. The relation between vapor pressure and vapor lock has been treated previously[4], so that the present paper will be limited more specifically to fuel-system design in its relation to vapor lock and to the permissible fuel vapor pressure for satisfactory engine operation.

The general equation[5] between vapor-locking temperature and Reid vapor pressure is as follows:

$$t = 95.7 - 140 \log (p_r/p) \qquad (1)$$

where p is the external pressure, in pounds per square inch, on the gasoline at the point in the fuel system where vapor lock occurs; p_r is the Reid vapor pressure of the gasoline, in pounds per square inch at 100 deg. fahr.; and t is the temperature of the gasoline at which vapor lock occurs.

Equation (1) involves two assumptions: namely, that the gasoline has a conventional distillation curve and that the volume of vapor passing through the fuel line equals the volume of liquid gasoline before the vapor lock occurs. In general, the average error resulting from these assumptions should not be greater than 2 deg. fahr. In most usual systems, vapor lock occurs at a point where there is little hydrostatic pressure or suction on the gasoline, in which case p can be taken simply as the outside air pressure, which is normally 14.7 lb. per sq. in. at sea level and 10.2 lb. per sq. in. at 10,000 ft. altitude. It should be pointed out that the term vapor pressure, as commonly used in connection with gasoline, refers specifically to the Reid vapor pressure measured at 100 deg fahr., and it will be so used throughout this paper.

For a fuel of given vapor pressure in a given car, the question as to whether the vapor-locking temperature will be reached depends upon the outside air temperature and upon the increase in temperature of the fuel above that of the atmosphere due to heating while the fuel is passing through the feed system. Thus, under each set of conditions, there is a limiting atmospheric temperature at which heating of the fuel in the feed system will raise its temperature just enough to cause vapor lock. Accordingly, equation (1) can be written in the form

$$t_a + \Delta t = 95.7 - 140 \log (p_r/p) \qquad (2)$$

where t_a is the limiting atmospheric temperature, in deg. fahr., for vapor lock and Δt is the difference between the atmospheric and the vapor-locking temperature. For any given fuel vapor pressure and any given atmospheric pressure, the design of fuel system affects Δt and determines the highest permissible atmospheric temperature before boiling of the fuel, and hence vapor lock occurs. It is evidently desirable that Δt be kept as small as possible, which means that heating of the fuel in the feed system should be reduced to the minimum. If protection from vapor lock is to be assured, reduction in heating of the fuel is necessary, since most refiners are keeping the vapor pressure of their product down to the minimum value compatible with other requirements of the fuel.

As a basis for discussion of the relation between fuel-system design and vapor lock, it is convenient to subdivide present-day fuel systems into three types:

(1) Gravity-feed systems
(2) Vacuum-tank systems
(3) Fuel-pump systems

[1] Publication approved by the Director of the Bureau of Standards of the United States Department of Commerce.

[2] S.M.S.A.E.—Physicist, Bureau of Standards, City of Washington.

[3] Junior physicist, Bureau of Standards, City of Washington.

[4] See S.A.E. JOURNAL, July, 1930, p. 93.

[5] See S.A.E. JOURNAL, December, 1931, p. 447.

These will be considered in the order named from the standpoint of the information obtained at the Bureau of Standards during the last two years.

VAPOR LOCK IN GRAVITY-FEED SYSTEMS

The essential principle of a gravity-feed system is that there shall be at all times sufficient hydrostatic pressure to permit the carbureter to function properly. Since the presence of bubbles of gas or vapor in the line may reduce the hydrostatic pressure materially, this type of system is very sensitive to small temperature changes near the vapor-locking point of the gasoline. On the other hand, fuel temperatures in a gravity-feed system can usually be kept within safe limits because of its simplicity. Still further, because of the location of the supply tank in current models, more weathering of the gasoline may occur than with those systems in which the supply tank is at the rear. This stabilization of the gasoline lowers the vapor pressure and hence the vapor-locking tendency.

Numerous flow experiments[6] in the laboratory have shown that vapor lock in a gravity-feed system occurs at the predicted temperature. The results are illustrated in Fig. 1, where the predicted vapor-locking temperatures are plotted against the observed values corresponding to operation both at sea level and at 8000 ft. altitude. The agreement is within 2 deg. fahr. on the average. These data were obtained on an installation in which the number of bends was reduced to the minimum, and therefore the observed temperatures represent maximum values. Additional experiments[7] with less ideal fuel-line installations indicated that interruption of flow might occur at considerably lower temperatures than those predicted from equation (1). It was noticed that the effect on the flow of variations in the installation largely resulted from the restrictions imposed on the elimination of gas or vapor. If the vapor escaped readily, no reduction in flow was observed. If, however, the vapor tended to collect, the hydrostatic head of liquid was reduced and hence the flow of gasoline was decreased.

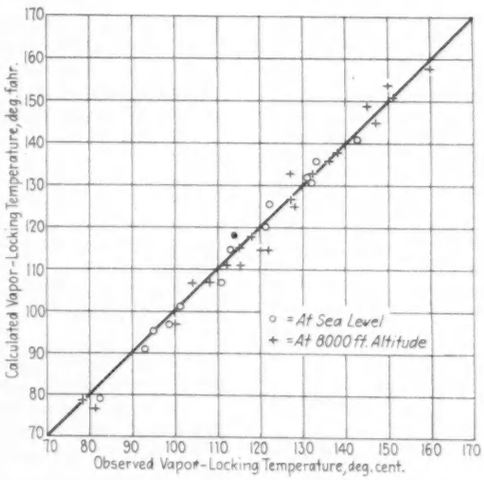


FIG. 1—CALCULATED AND OBSERVED VAPOR-LOCKING TEMPERATURES OF GASOLINES WITH GRAVITY FEED

Road tests on a number of cars equipped with gravity-feed systems have shown that there may be considerable temperature difference between the fuel-tank outlet and the carbureter inlet. Two general cases occur, in one of which there is a temperature decrease from the tank to the carbureter and in the other a temperature increase between these points. In the first case, the temperature of the gasoline as it leaves the tank seems to be the best criterion for predicting the occurrence of vapor lock on the road. In the second case, the choice of location of the position in the line at which the temperature can be considered significant depends upon the design of the line connecting the two points and upon the increase in temperature. With systems having a sediment bowl near the tank and in which there is little temperature increase between the sediment bowl and the carbureter, as is the case with a number of models on the road today, then the temperature at the outlet from the sediment bowl is considered to be the most significant. If, however, the sediment bowl is attached to the carbureter, the temperature of the fuel at the inlet to the sediment bowl seems to be the best criterion for prediction of vapor lock.

VAPOR LOCK IN VACUUM-TANK SYSTEMS

A vacuum-tank system is essentially a gravity-feed system from an auxiliary tank to the carbureter, combined with a suction-lift system from the main-supply tank to the auxiliary tank. Everything that has been said regarding gravity-feed systems is applicable to that part of a vacuum-tank system from the vacuum tank to the carbureter. However, two additional factors enter; namely, refilling of the vacuum tank and weathering of the gasoline in the vacuum tank.

Refilling of the vacuum tank is accomplished automatically by means of suction from the inlet manifold. The amount of manifold suction necessary depends upon the difference in level between the main tank and the vacuum tank and upon the size of the opening leading from the vacuum tank to the inlet manifold. If the suction lift is 2.5 ft., a suction of about 0.8 lb. per sq. in. in the vacuum tank would be required to overcome the hydrostatic head. To produce a suction of 0.8 lb. per sq. in. in the vacuum tank during the short time permissible, it is necessary to have a somewhat higher suction in the inlet manifold, since a considerable volume of gas and vapor has to be removed through a small opening.

Not only is it necessary to remove the gas and vapor in the vacuum tank at the time refilling commences, but it is also necessary to remove vapors formed by the inflowing gasoline. In very hot weather or during full-throttle operation, such as on a long hill, there may not be sufficient suction to lift the gasoline from the supply tank to the vacuum tank, and engine stoppage results. While this inherent fault of vacuum-tank systems is not directly attributable to vapor lock, it is indirectly related to it because it involves the same factors: namely, the vapor pressure of the gasoline and the ability of the system to handle vapor. The difficulty can be practically remedied by the use of special devices to increase the suction.

Considerable weathering of the gasoline may occur during the process of filling the vacuum tank, and additional weathering may occur in the vacuum tank because of the high fuel temperatures frequently found there. It is therefore of interest to have information on the change in vapor pressure between the rear tank and the vacuum-tank outlet, for this change has a very direct bearing on the possibilities for vapor lock between the vacuum tank and the carbureter. The apparatus shown in Fig. 2 was set up to obtain this information.

Description of Apparatus

The gasoline was placed in the tank *A*, the temperture of which could be controlled by a heating coil through which hot oil was circulated by a pump. From *A*, the gasoline flowed through a heat interchanger, *B*, heated by hot oil, and thence into the vacuum tank *C*, which was placed in a bath through which hot oil could

[6] See S.A.E. JOURNAL, August, 1930, p. 218.
[7] See S.A.E. JOURNAL, October, 1930, p. 444.

TABLE 1—SPECIFICATION DATA ON GASOLINES USED

Fuel No.	Distillation Temperature at Stated Percentages Evaporated, Deg. Cent. (Deg. Fahr.) 10%	50%	90%	Reid Vapor Pressure at 100 Deg. Fahr., Lb. per Sq. In.
70	77 (171)	125 (257)	180 (356)	5.0
71	63 (145)	131 (268)	187 (369)	7.8
72	57 (135)	128 (262)	185 (365)	9.0
73	62 (144)	125 (257)	175 (347)	8.5
74	56 (133)	121 (250)	181 (358)	9.0
75	42 (108)	76 (169)	174 (345)	11.9
76	64 (147)	126 (259)	181 (358)	8.0
77	59 (138)	125 (257)	181 (358)	9.4
78	58 (136)	115 (239)	177 (351)	9.5
79	59 (138)	106 (223)	152 (306)	8.7
80	61 (142)	112 (234)	182 (360)	8.0
81	63 (145)	108 (226)	178 (352)	7.9

be circulated. The vacuum tank was used in the normal manner, being filled by suction and draining continuously into a container provided for this purpose. At the completion of each run, the gasoline in the vacuum tank was withdrawn into the cooled container *D* through the cooling bath *E*, containing ice, and then through the valve *F*. A thermocouple was located in the liquid in the lower chamber of the vacuum tank.

Preliminary to the main investigation, a study was made of the effects of suction lift, volume of flow, and suction on the tank. Within narrow limits, it was found that these variables had little effect on the results at constant temperature, and it was concluded that temperature of the gasoline was the most important variable. Accordingly, a set of standard conditions was chosen; namely, suction lift, 2.5 ft.; manifold vacuum, 8 in. of mercury; flow, about 2 gal. per hr. Data were obtained under these conditions on 12 commercial gasolines, which are described in Table 1. Measurements of Reid vapor pressure at 100 deg. fahr. were made on the original gasolines and on the samples obtained after an experiment at each temperature.

Typical curves of Reid vapor pressure plotted against temperature are shown in Fig. 3. It is observed that decrease in vapor pressure occurs slowly at first, as the temperature of the gasoline in the vacuum tank increases, and then becomes more rapid at the higher temperatures. The arrows represent the vapor-locking temperatures predicted from distillation data. It is

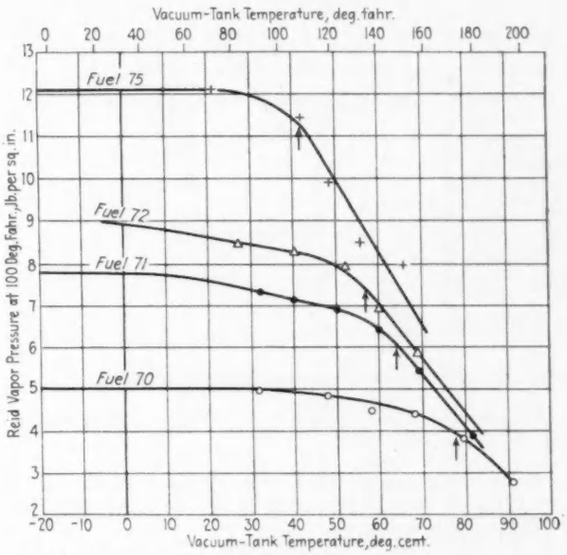

Vacuum-Tank Temperature, deg. fahr.
0 20 40 60 80 100 120 140 160 180 200
Fuel 75
Fuel 72
Fuel 71
Fuel 70
Reid Vapor Pressure at 100 Deg. Fahr., lb. per sq. in.
13 12 11 10 9 8 7 6 5 4 3 2
-20 -10 0 10 20 30 40 50 60 70 80 90 100
Vacuum-Tank Temperature, deg. cent.

FIG. 3—TYPICAL CURVES SHOWING DECREASE IN VAPOR PRESSURE CAUSED BY WEATHERING IN THE VACUUM TANK AT VARIOUS TEMPERATURES

seen that considerable drop in vapor pressure occurs in some cases before the predicted vapor-locking temperature is reached. This is attributed to the presence in the gasoline of propane, which would weather off at temperatures below those at which appreciable amounts of the butanes and higher fractions would begin to come off. For this reason the distillation data are more suitable than is the Reid vapor pressure in predicting the vapor-locking temperature, as the former gives an indication of the vapor pressure of the gasoline line after the propane is removed.

Relation Between Propane and Vapor Pressure

From the distillation and Reid-vapor-pressure data on the original samples, it is possible to predict how much the vapor pressure will change because of loss of the propane. In a previous paper[8] it was shown that,

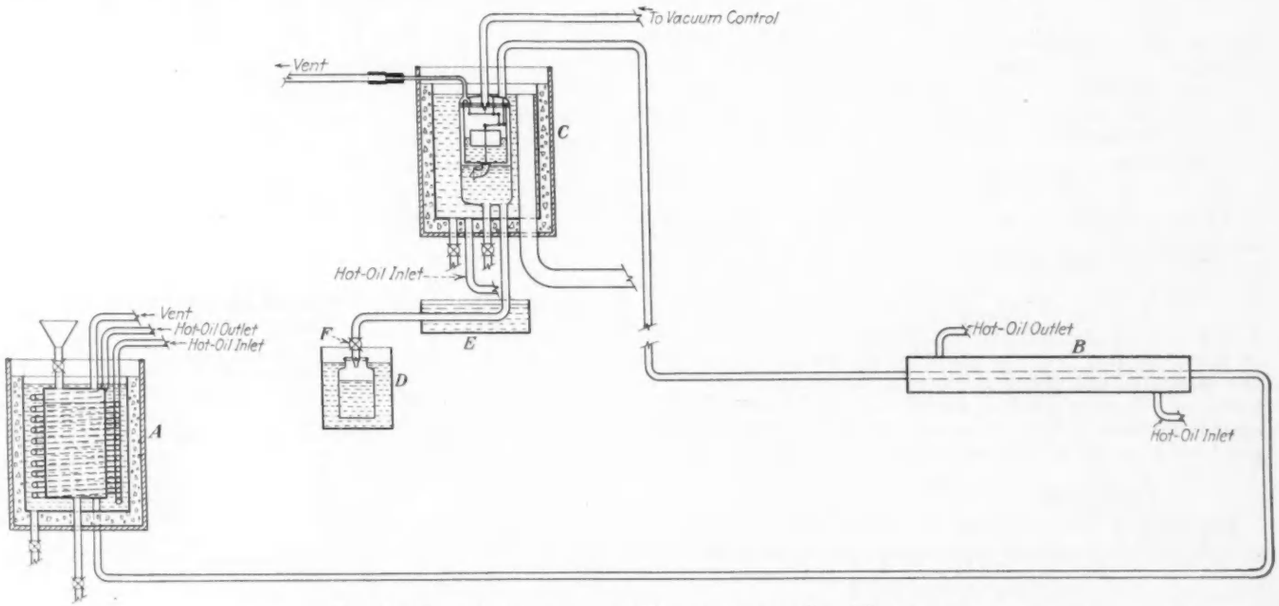


FIG. 2—TEST APPARATUS FOR VACUUM-TANK FEED SYSTEM

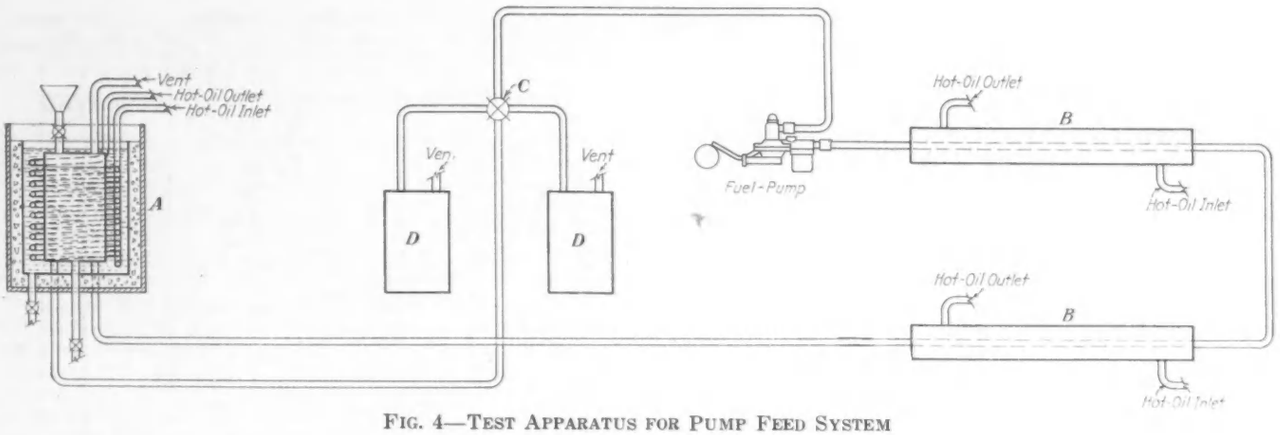


FIG. 4—TEST APPARATUS FOR PUMP FEED SYSTEM

for propane-free gasolines, the gas-free vapor pressure is related to the 10-per-cent point of the gasoline according to the equation:

$$\log\ (\pi/14.7) = A\left[\ 1 - \frac{\theta + 460}{560}\right] \qquad (3)$$

where A is a constant characteristic of each gasoline, dependent upon the slope of the distillation curve at the 10-per-cent point; π is the vapor pressure, in lb. per sq. in. at 100 deg. fahr.; and θ is the 10-per-cent point of the gasoline, in deg. fahr. Equation (3) holds accurately only for propane-free gasolines, and therefore θ should be the 10-per-cent point of the gasoline after removal of the propane; that is, the temperature at a percentage evaporated for the original gasoline equal to 10 plus the volume percentage of propane. This assumes that all of the propane is distilled off before the 10-per-cent point is reached, which is probable.

In the same paper it was shown that the Reid vapor pressure p_r multiplied by the factor 1.1 is equal to the gas-free vapor pressure. Accordingly, the difference between 1.1 p_r and π, as given by equation (3), is a measure of the pressure exerted by the propane in the gasoline. The relation between the pressure exerted by propane dissolved in a gasoline and the percentage volume of propane is as follows:

$$S = 0.441\ \ p \qquad (4)$$

where p is the pressure exerted by propane dissolved in gasoline and S is the percentage of propane by volume.

This equation is based on the investigation of the solubility of propane in gasolines which has been previously reported[8]. Since $p = 1.1\ \ P_r - \pi$, equation (4) becomes

$$S = 0.441\ [1.1\ p_r - \pi] \qquad (5)$$

In using equation (5), an approximate value of π is computed based on the 10-per-cent point of the original gasoline, and this in turn is used to calculate an approximate value of S. The temperature at a percentage evaporated equal to $10 + S$ is now read on the distillation curve of the gasoline, corrected for loss, and this is taken as the 10-per-cent point of the gasoline after the propane has been removed. This more accurate value of θ is now used to compute π, and hence S. One approximation ordinarily is sufficient to give a fairly good estimate of the propane content of the gasoline.

Predicting Vapor-Pressure Change

For each of the gasolines on which vacuum-tank experiments were made, the propane contents were computed and the pressures corresponding to each of these propane contents were subtracted from the vapor pressures of the original gasolines. These computed vapor pressures, corresponding to the propane-free gasolines, are shown in Table 2, where a comparison is made in each case with the observed vapor pressure at a temperature equal to the 10-per-cent point of the gasoline.

On the average, the predicted vapor pressures at the vapor-locking temperatures agree with the observed values within 0.2 lb. per sq. in. From this it may be concluded that most of the change in vapor pressure from weathering in vacuum tanks is caused by loss of propane and that, in a propane-free gasoline, the change would not exceed 0.2 lb. per sq. in until the temperature is reached at which the gasoline commences to boil. Most commercial gasolines, however, do contain propane, so that considerable weathering in the vacuum tank should be expected. The observed losses in vapor pressure before the depropanized gasolines began to boil are given in the last column of Table 2 for the 12 gasolines studied. The average decrease is 1.2 lb. per sq. in., which would mean an increase in vapor-locking temperature from 133 to 143 deg. fahr. in the case of a gasoline having an original vapor pressure of 8 lb. per sq. in. A much larger decrease in vapor pressure would result if the gasoline boiled in the vacuum tank, but in this event vapor lock would be expected from interruption of the fuel flow between the vacuum tank and the carbureter.

Vapor lock in a vacuum-tank system does not ordinarily occur unless the gasoline is heated in the vacuum tank almost to the boiling temperature, because the temperature increase of the fuel between the vacuum-tank outlet and the carbureter inlet is usually small. The best criterion for predicting the occurrence of vapor lock is the fuel temperature at the vacuum-tank

TABLE 2—LOSS OF VAPOR PRESSURE IN VACUUM-TANK EXPERIMENTS

Fuel No.	Reid Vapor Pressure, Lb. per Sq. In.			
	Original	After Weathering		Loss
		Observed	Calculated	
70	5.0	3.9	4.0	1.1
71	7.8	6.0	6.1	1.8
72	9.0	7.4	7.4	1.6
73	8.5	6.2	6.4	2.3
74	9.0	7.0	7.2	2.0
75	11.9	11.3	11.6	0.6
76	8.0	6.2	6.1	1.8
77	9.4	7.3	7.2	2.1
78	9.5	7.1	7.2	2.4
79	8.7	6.1	6.4	2.6
80	8.0	6.4	6.8	1.6
81	7.9	6.2	6.4	1.7

[8] See S.A.E. JOURNAL, July, 1930, p. 93.
[9] See S.A.E. JOURNAL, July, 1930, p. 93.

outlet, and the vapor-pressure value to be used is not that for the original gasoline but that for the depropanized gasoline.

VAPOR LOCK IN FUEL-PUMP SYSTEMS

The essential feature of a fuel-pump system is the use of a mechanical pump to transfer the gasoline from the rear tank to the carbureter float-bowl. The fuel is lifted by suction to the pump, ordinarily through a vertical distance of about 1 ft., and is then transferred under a pressure of about 3 lb. per sq. in. to the carbureter. Since there is usually little change in fuel temperature between the fuel-pump outlet and the carbureter inlet, the additional pressure on the fuel is effective in preventing vapor lock in this part of the system. Accordingly, the problem of vapor lock in a fuel-pump system is concerned with that part of the fuel line on the suction side of the pump and resolves itself into questions of fuel temperature in this part of the system and the capacity of the pump for handling vapor. This latter question, involving the efficiency of the pump at various temperatures, has been given special study in connection with a number of gasolines.

The apparatus used for the pumping-efficiency experiments is shown in Fig. 4. The gasoline was placed in the tank *A*, the temperature of which could be controlled by a heating coil through which hot oil was circulated by a pump. From *A*, the gasoline flowed through the heat interchangers *B*, heated by hot oil, and thence into the fuel-pump. From the outlet side of the pump, the fuel passed to the three-way valve *C* which could be set so that the fuel went back into the tank *A* or into either of the containers *D* for measurement of the volume of flow. A thermocouple, not shown in the diagram, was located in the gasoline stream at the entrance to the fuel-pump. In making an experiment, the gasoline in *A* was brought to the appropriate temperature; the fuel-pump was started; the gasoline was allowed to flow around the system until a steady state was reached; and then the three-way valve *C* was turned so as to measure the volume of gasoline being pumped per unit of time. Care was taken to replace the gasoline sample when there was an indication of appreciable weathering as determined by distillation characteristics.

Effective Delivery Stops at Critical Temperature

Data were obtained on six of the commercial gasolines described in Table 1 at each of four pump speeds (2000, 1000, 500 and 250 r.p.m.) and over a temperature range in each case up to the vapor-locking temperature. Because of the particular experimental procedure employed in circulating the gasoline to reach thermal equilibrium, the propane in the samples weathered off almost immediately, and hence the vapor-locking temperatures correspond to the 10-per-cent points as given in Table 1, rather than to values computed from the vapor pressures given in this table.

TABLE 3—PUMPING CAPACITY OF AUTOMOBILE FUEL-PUMP

Pump Speed, r.p.m.	Flow, at Stated Speeds, Gal. per Hr. 2000	1000	500	250
Fuel No.	*At 10 Deg. Cent. Above Vapor-Locking Temperature*			
70	4	3	2	1
71	4	3	2	1
72	4	3	2	1
75	3	2	2	1
78	5	4	2	1
80	4	3	2	1
	At Vapor-Locking Temperatures			
70	8	6	5	3
71	9	7	3	2
72	9	7	4	3
75	8	7	5	3
78	9	7	5	3
80	7	6	3	2
	At 10 Deg. Cent. Below Vapor-Locking Temperature			
70	20	17	15	12
71	20	18	12	8
72	22	20	15	10
75	27	25	21	18
78	22	18	15	12
80	18	15	13	9

A typical temperature-flow curve, which is shown in Fig. 5, indicates that the flow decreases markedly with increase in the temperature of the fuel being pumped. The arrow indicates the vapor-locking temperatures; and a small volume of flow is observed beyond the temperature at which vapor lock would be expected, indicating that the pump is capable of handling some vapor. However, it was found that the flow was spasmodic in all cases after the vapor-locking temperature was reached, so that the engine would probably stop or behave very erratically even though the total volume of flow, if delivered uniformly, was just sufficient to keep it running smoothly. The volumes of flow at various temperature intervals above and below the vapor-locking temperatures are shown in Table 3 for the six fuels. At or above the vapor-locking temperatures, there is not much variation between the different gasolines in volumes pumped, but there is considerable variation at 10 deg. cent. below the vapor-locking temperatures.

The temperature-flow curves for a typical gasoline are shown in Fig. 6, based on car speed instead of pump speed and assuming an average value for the relation between car speed and engine speed. It should be pointed out that the fuel temperatures given are ap-

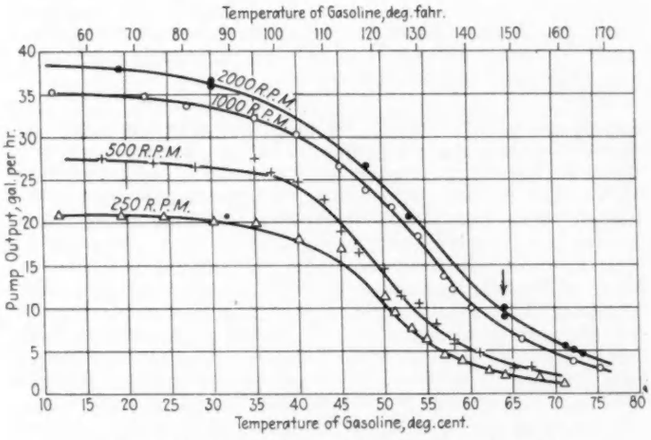


Fig. 5—Fuel No. 71 at Different Pump Speeds

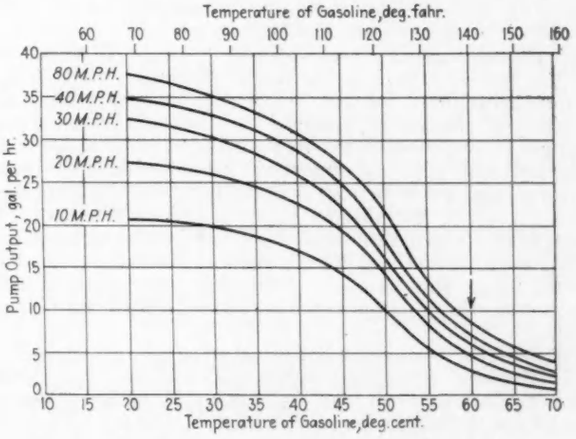

Temperature of Gasoline, deg. fahr.
60 70 80 90 100 110 120 130 140 150 160
80 M.P.H.
40 M.P.H.
30 M.P.H.
20 M.P.H.
10 M.P.H.
Pump Output, gal. per hr.
0 5 10 15 20 25 30 35 40
10 15 20 25 30 35 40 45 50 55 60 65 70
Temperature of Gasoline, deg. cent.

Fig. 6—A Typical Fuel, at Different Vehicle Speeds

FLOW FROM FUEL-PUMP AT VARIOUS TEMPERATURES

plicable to the fuel-pump inlet and that, in the experiments outlined, there was no temperature gradient across the pump. In most cars, there is an average gradient of about 10 deg. fahr. across the pump, so that the volumes of flow near the vapor-locking point would be appreciably less in actual practice than those indicated. In view of this temperature gradient and the fact that the flow is erratic as soon as the vapor-locking temperature is reached, the fuel temperature at the pump inlet appears to be the best criterion of vapor lock with this type of system.

IMPROVEMENTS IN FUEL-SYSTEM DESIGN

It has been pointed out in preceding sections that there is a point in each type of fuel system at which the fuel temperature is a significant criterion for vapor lock in that system. When the temperature at this point reaches the vapor-locking temperature, as predicted from the Reid vapor pressure of the gasoline flowing through the system, then interruption of flow because of vapor lock may be expected. It should be kept in mind that the vapor pressure of interest is that of the gasoline in the fuel system at the time vapor lock occurs, that in warm weather the average loss in vapor pressure between the refinery and the supply tank of the car is about 1 lb. per sq. in. and that further loss in vapor pressure may occur while the gasoline is in the car. Assuming that a gasoline of given vapor pressure is in the fuel system of the car, there are three major ways in which fuel-system design and installation can be changed to assist in the avoidance of vapor lock when operating at any given atmospheric temperature:

(1) By increasing the capacity of the system for handling vapor
(2) By decreasing the amount of heat which gets into the fuel system
(3) By putting pressure on the fuel.

These changes in fuel-system design and installation will be discussed in the order named. Since fuel-pump systems are used in most makes of automobile and since they have given the most trouble from vapor lock, the discussion will be confined to this type of system.

Capacity for Handling Vapor

The capacity of a fuel-pump system for handling vapor can probably be increased somewhat, although this change by itself should not be expected to result in a marked improvement. Two factors enter; namely, the installation of the fuel line from the rear tank to the pump, and the capacity of the pump itself for handling vapor. The optimum installation of fuel line would be one in which the tubing used is of such size that the maximum linear velocity of flow is about 0.5 ft. per sec., in which the cross-sectional area is the same throughout its entire length, and in which the number of bends is reduced to the minimum. Any change in cross-sectional area, either an increase or a decrease, will give an opportunity for bubbles of vapor to form and grow in size. Each bend in the line likewise gives the bubbles of vapor a chance to grow, although this can be reduced by wide bends rather than sharp ones. Further, for an ideal installation, the line should slope continuously from the rear tank to the pump and there should be no traps where vapor can collect.

Increase of the vapor-handling capacity of the pump is intimately connected with the design, and there seems to be no reason why a pump could not be designed which would handle large volumes of vapor. There is a practical limit to the effectiveness of this, however, from the standpoint of vapor lock, for each degree rise in temperature above the vapor-locking temperature may cause a very marked increase in the amount of vapor formed. Hence it is doubtful whether an increase in the vapor-handling capacity of the pump would serve to raise by more than a very few degrees the temperature at which vapor lock would actually occur. A further limitation in this respect arises from the fact that the flow becomes intermittent even before the vapor-locking temperature is reached, so that, even if the average volume of liquid flow is adequate, the mixture ratio will fluctuate considerably and the engine is liable to stop because of a temporary leanness of the mixture.

Fuel-Line Temperatures

Improvement in design and installation of fuel systems to decrease the amount of heat which gets into the fuel is the simplest way of minimizing the occurrence of vapor lock in the case of the existing type of fuel-pump system. The practical limit in this direction is the atmospheric temperature, because a reduction in fuel temperature below that of the atmosphere is not feasible without recourse to refrigeration. In order to keep the fuel from being heated to above atmospheric temperature one of two things is necessary. In the first case, the gasoline in the rear tank must be protected from heat from the exhaust pipe and reflected heat from the road, and there must be no heating between the rear tank and the pump. In the second case, any heat taken up by the fuel in the rear tank must be removed while the fuel is flowing between the tank and the pump, which implies the use of a fuel radiator, suitably installed in the air stream.

The requirement that the fuel temperature at the pump inlet be not higher than atmospheric temperature is a drastic one, and in practice strict adherence to this requirement is not necessary with present-day gasolines. What is required is that the amount of heating up to the fuel-pump inlet shall be so small that the temperature of the gasoline at the fuel-pump is not more than 10 to 15 deg. fahr. above atmospheric temperature, even during idling.

The temperature of the gasoline in the rear tank is 18 deg. fahr. above the atmospheric temperature[10] in the average car on the road today, when running at 40 m.p.h., and it varies between 8 and 31 deg. in individual models. In order to design an efficient fuel-feed system, it is therefore desirable that heating of the gasoline in the rear tank be reduced. This should not be very difficult, for it would only require that the tank be shielded from engine and exhaust heat carried back inside of the frame channel and from heat reflected from the road. Having reduced the heating in the rear tank, the next step is to minimize the heating between the rear tank and the pump.

When the average car on the road today is running at speeds of from 20 to 60 m.p.h., the temperature of the fuel increases by 12 deg. fahr. in passing from the tank to the pump, and in many models the increase is more than 20 deg. On idling, the average increase between these two points is 30 deg., and in many cases there is an increase of more than 40 deg. In a number of cars, excessive heating of this portion of the fuel system is due to close proximity of the line to the exhaust pipe. Shifting the fuel line to the other side of the car should reduce the heating considerably in such cases. A preferable location of the line, from the standpoint of heating, is on the outside of the car frame. This avoids heat transfer from the engine and the exhaust pipe; and, if the line is properly mounted in the air stream and in poor thermal contact with the frame, there should be no heating of the gasoline be-

[10] See S.A.E. JOURNAL, December, 1931, p. 447.

tween the rear tank and the point at which the line enters the engine compartment.

Examples of temperature decreases effected by relocating the line outside of the frame channel are given in Table 4. The average decrease in temperature in these four cars is 16 deg. fahr., which is equivalent to an increase in permissible gasoline-vapor pressure of about 2.5 lb. per sq. in. It is seen that in two cases the temperature dropped 1 deg. in passing from the tank to the pump. A drop of 10 deg. between the rear tank and the pump has been observed in one car, as the result of cooling by the air stream. In the cases of the cars referred to in Table 4, similar temperature decreases were observed on idling.

In installing the fuel line, it is desirable to have as little length as possible in the engine compartment, and this short length should be thermally insulated unless cooling by the air stream compensates for the heat received from the engine. Thus, if the pump is mounted directly behind the radiator, thermal insulation probably is unnecessary, while if the pump is mounted on the crankcase in the customary way, it is preferable in most cases to use thermal insulation. Careful installation of the fuel line in the engine compartment

TABLE 4—DECREASES IN TEMPERATURE EFFECTED BY RELOCATION OF THE FUEL PIPE

Car	Temperature Difference between Tank and Pump, Deg. Fahr.			Increase in Permissible Vapor Pressure, Lb. per Sq. In.
	Line Inside	Line Outside	Decrease	
M-1	11	—1	12	2.8
N	22	—1	23	5.0
S	18	2	16	3.5
13	23	8	15	3.4

is particularly helpful in reducing fuel temperatures during idling.

The final step in reducing fuel temperatures is concerned with the fuel-pump. In the usual installation, the fuel-pump is mounted on the crankcase, frequently in such a position that it is shielded from the air stream and receives a considerable amount of heat from the exhaust manifold. Proper location of the pump with respect to the exhaust manifold is very desirable, but the most important change which can be made in the pump is in the method of lubricating it. The fuel-pump is not designed to be an oil cooler, and it seems entirely unnecessary to circulate large quantities of hot crankcase oil through the fuel-pump shell to lubricate it. The temperature increase of the fuel between the inlet and outlet of the pump in the average car on the road is 10 deg. fahr. while running and about 15 deg. while idling. Since the fuel is entering the pump with a linear speed of ¼ to 1 ft. per sec., it is apparent that the heating must be excessive to raise the temperature of the fuel by the amount indicated. A redesign of the pump to avoid the circulation of hot crankcase oil through the shell would have a marked effect in reducing the heating, and in some models in which this has been done the temperature increase across the pump has been practically eliminated.

By making this change in the method of lubrication, it is also possible to relocate the pump so that heat transfer from the engine is reduced and cooling by the air stream is increased. If heating is thus reduced, then for the same degree of vapor lock with a given fuel the fuel temperature at the inlet to a pump showing no temperature increase across it is several degrees higher than in the case of the average pump in use on present cars, in which the temperature increase across it averages 10 to 15 deg. fahr.

Pressure-Feed Systems

The third major way in which vapor lock can be avoided is by putting pressure on the fuel. In present systems, the gasoline is forced from the fuel-pump to the carbureter float-bowl under a pressure of about 3 lb. per sq. in. Pressure on the gasoline in this part of the system is of comparatively little use from the standpoint of vapor lock, for there is usually little change in fuel temperature between the pump and the carbureter. The part of the line where pressure should be applied is that part in which heating of the fuel occurs, and in most existing systems this section is under a slight suction rather than pressure. If pressure is to be used as a means for reducing vapor lock, it should be applied at a point nearer the tank. Two general methods are available: the use of a pump with remote drive or with electric drive, and the use of gas pressure on the tank. While either of these methods is theoretically capable of reducing vapor lock, each one introduces its own peculiar difficulties.

The design of a remote drive for a fuel-pump situated near the rear tank probably offers greater difficulties than the design of a suitable electric device, while the latter may offer greater fire hazard unless very carefully constructed with this in mind. If a fuel-pump driven by an electric motor is used, the speed will be essentially constant and hence a by-pass line back into the tank may be required. By placing the pump near the rear tank, vapor lock on the suction side will be almost entirely eliminated unless gasolines with very high vapor pressures are used, for the temperature of the fuel in the tank is usually considerably below the vapor-locking temperature.

Forcing the gasoline to the carbureter under a pressure of 3 to 5 lb. per sq. in. raises the vapor-locking temperature by 20 to 30 deg. fahr., respectively, so that the occurrence of vapor lock up to the carbureter would be greatly reduced even without much care in the installation of the fuel line.

However, if the gasoline enters the carbureter float-bowl at a temperature much above the vapor-locking temperature at the prevailing atmospheric pressure, there is likely to be such violent boiling that the engine will stop because of overrichness of the mixture. Accordingly, even with this type of pressure feed, it is desirable to keep the fuel temperatures low by careful installation of the line, and it is probably desirable to make provision for venting fairly large volumes of vapor from the float bowl into the inlet manifold.

The elimination of a fuel-pump and the use of gas pressure to force the gasoline into the float bowl can be accomplished readily in two different ways. The engine can be used to drive an air compressor, but this involves considerable fire hazard. This fire hazard may be reduced somewhat by using exhaust gas, tapped from one of the cylinders, which can be made to maintain the desired pressure automatically. Some purification of the gas is necessary, particularly the removal of acidic and sulphuric compounds, which not only would be corrosive but might catalyse gum formation in the fuel. The same difficulties in connection with large volumes of vapor escaping in the float bowl are involved in this case also, and they are increased somewhat because of the high solubility of carbon dioxide in gasoline.

Vapor Lock in the Carbureter

Under all ordinary conditions, vapor lock rarely occurs in the carbureter while the car is running. Occasionally, however, the position of the carbureter is such that the fuel temperature at this point is much higher than at any other point in the system, and vapor

(*Concluded on p.* 142)

Compression-Ignition Characteristics of Injection-Engine Fuels

Annual Meeting Paper

A. W. Pope, Jr.,[1] and J. A. Murdock[2]

NEEDING to study the ignition characteristics of Diesel-engine fuels, the authors developed an idea that was presented at a meeting of the Research Committee of the Society last June. The idea was that engine tests must be the basis of evaluation. A C. F. R. engine was converted into a variable-compression Diesel engine by substituting a new piston and a fuel-injection system for the original piston and ignition system.

Test methods that have been developed are reported, together with some results that show the practicability of the procedure and its substantial agreement with data secured in other ways. It is suggested that, as some of the most desirable qualities of gasoline are undesirable for Diesel fuel, and vice versa, fuels may be divided in the future on that basis, and Diesel and gasoline engines may approach each other in compression ratio.

Discussers are warm in their appreciation of the work reported, one of them describing it as the most fundamental work on fuels since the development of the bomb test. Another discusser reports work on gasoline with a C. F. R. engine in which the electric ignition was not used and the autoignition temperature was determined by increasing the compression to the point at which autoignition occurred. That point was found to be quite definite and to check well with data in the paper.

SOME YEARS AGO, H. R. Ricardo popularized the understanding of the influence of compression ratio on Otto-cycle performance, with the result that engine design awoke from its stagnation and advanced rapidly to its present state. Recently Mr. Ricardo seems to have done the same thing for the Diesel cycle by popularizing his conception of the three stages of injection-engine combustion. As in the case of the Otto cycle, so with the Diesel, engine development soon led to a question of fuels; in the Otto cycle it was detonation, in the Diesel cycle, ignition temperature.

In addition to the Ricardo works, two papers have been presented in England during the last year which have correlated the influence of fuel-ignition characteristics to engine performance.

L. J. LeMesurier and R. Stansfield[3] showed, by tests on several engines, the influence of ignition lag on the rate of pressure rise and the roughness of the engine; and G. D. Boerlag and J. J. Broeze[4] have corroborated most of this work and developed a method of rating fuels on the basis of their ignition lag.

At an S.A.E. Research Committee meeting in June, 1931, the question of a method of attack for studying Diesel-fuel ignition temperatures was very thoroughly discussed. The idea that an engine test must be the basis of the method was very convincingly presented. We, of course, recognized the many advantages of the Cooperative-Fuel-Research variable-compression engine as an instrument for this work, and when, a few weeks later, the Diesel-engine development in our own company suddenly encountered the problem of measuring Diesel-fuel ignition characteristics, work was started to make a conversion of the C. F. R. carbureter engine to a variable-compression injection engine.

The object of this work has been to indicate the possibilities of developing an engine method of rating Diesel fuels on the basis of the temperature-time factor of their ignition, the index to this temperature-time factor being the critical compression ratio for audible combustion. Suppression of the influence of engine variables is intended to be accomplished by matching the unknown fuel with a standard-reference-fuel scale. This is the method used in the C. F. R. octane rating.

Results of the work have been very gratifying. The critical compression ratio between audible and inaudible combustion is easily maintained within 0.007-in. variation in combustion-chamber height. This means that a movement of the cylinder of 0.007-in. will bring in or throw out audible combustion. This is 0.07 of a ratio at 8:1 compression and 0.18 of a ratio at 12:1.

Fuel Mixtures for Reference Scale

Fig. 1 shows the critical compression ratio for a series of kerosene-benzol mixtures as determined by two methods. The lower curve was obtained by operating the engine under standardized conditions and then lowering the ratio until firing ceased. The upper curve was obtained by motoring the engine over under standardized conditions and locating the compression ratio at which audible combustion started. This last method has many advantages which will be explained later, and it is used on all the other tests reported.

Fig. 2 shows indicator cards taken with three of the kerosene-benzol mixtures, covering the range from high to low compression ratios. The cards are taken at steps in compression ratio from 19:1 down to the critical ratio or until firing ceases. They illustrate the point made by Ricardo that raising the compression ratio will make a rough fuel burn more smoothly. The cards also agree with results obtained by the other writers mentioned above. As the compression ratio is lowered, the ignition lag and the rate of pressure rise increase until extremely low ratios are reached, when the rate of pressure rise decreases again. This trend is audibly apparent in the operation of the engine. These cards also indicate the desirability of low-ignition-temperature fuels for injection-engine operation.

Fig. 3 shows the influence of mixtures of a very rough-running Diesel fuel and kerosene on the critical compression ratio of kerosene. This Diesel fuel, which

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[2] Experimental Diesel engineer, Waukesha Motor Co., Waukesha, Wis.

[3] See *Journal of the Institution of Petroleum Technologists*, July, 1931, p. 387.

[4] See *Engineering*, Dec. 4, 1931, p. 687.

was supplied as a commercial fuel, caused a great deal of trouble in the commercial Diesel engines of our company. A mixture of this fuel with kerosene makes a good secondary reference scale, as it covers the range of most commercial Diesel fuels so far tested.

Octane and heptane suggest themselves for a primary reference scale. Fig. 4 shows the range of compression ratios covered. It also shows the closeness of agreement of critical-compression-ratio ratings taken on three fuels and on their octane-heptane equivalent as determined in the carbureter engine. It is not expected that such close agreement will exist with all fuels. Heptane-octane mixtures have some disadvantages as reference standards. Heptane does not go to as low a ratio as is desirable; and the lubricating qualities are very poor. This caused some difficulty with the injection system, but it can be overcome by further development. Addition of 5 per cent of lubricating oil provided good lubrication but affected the critical compression ratios appreciably. If the octane-heptane scale were used for primary reference purposes, it would be advisable to designate it as a heptane scale. A high reading then would indicate desirability, and the heptane name would distinguish it from the present octane rating for carbureter engines.

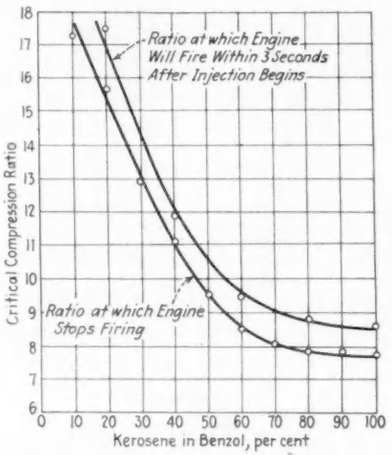

Ratio at which Engine Will Fire Within 3 Seconds After Injection Begins
Ratio at which Engine Stops Firing
Critical Compression Ratio
Kerosene in Benzol, per cent

FIG. 1—INFLUENCE OF BENZOL ON THE CRITICAL COMPRESSION RATIO OF KEROSENE

Determined in Variable-Compression Engine Running at 600 R.P.M. with Jacket Temperature 210 Deg. Fahr., Air 65-75 Deg., and Injection of 0.023 Cc. at 1000 Lb. per Sq. In. at 12-Deg. Advance

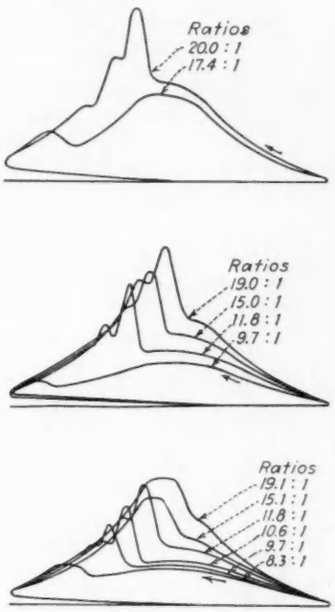


FIG. 2—INDICATOR CARDS ILLUSTRATING THE INFLUENCE OF COMPRESSION RATIO ON IGNITION LAG

A Blend of 20 Per Cent of Kerosene in Benzol Was Used for the Upper Card, Equal Parts Were Used for the Card at the Center, and All Kerosene for the Lower. Compression Ratios for the Various Diagrams Are Indicated on the Cards

A general idea of the relative position of engine fuels in respect to critical compression ratio is given in Fig. 6. It is apparent from the arrangement that the physical properties of the fuels, such as viscosity, gravity and flash, have no bearing on the ignition temperature of fuels.

Description of Apparatus

The tests were conducted on a standard Cooperative-Fuel-Research Engine converted for injection-engine operation by the installation of the special cupped piston shown in Fig. 7, which provides a combustion chamber conforming to the shape of the spray. A Bosch pump with adjustable advance is driven from the end of the camshaft, as shown in Fig. 8. Micrometer screws are provided for controlling both the quantity of the fuel and the advance angle of injection. A Bosch injector with pintle-type orifice is used. The angle at which injection starts in indicated by a very simple electrical indicator.

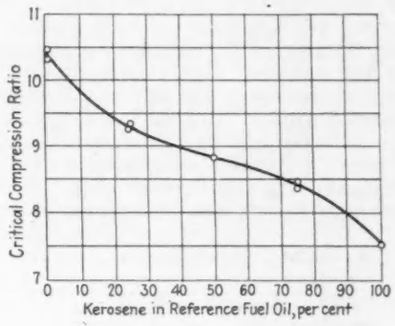


FIG. 3—INFLUENCE OF A ROUGH-RUNNING DIESEL FUEL ON CRITICAL COMPRESSION RATIO FOR KEROSENE

Contact points are located adjacent to the end of the needle-valve stem and adjusted to break when the needle-valve leaves its seat. Opening the contact points interrupts a current and induces a flash in the regular C. F. R. neon-tube spark-position indicator. The angle of injection start is thus always visible. A 500-watt electric air-heater is located on the inlet-pipe and a 1500-watt immersion-type heater is located in the water passage to maintain the jacket temperature at 210 deg. fahr. A synchronous motor, belted to the engine, maintains the engine speed constant at 600 r.p.m., regardless of whether or not it is firing.

Test Procedure

The original plan was to operate the engine under standardized conditions and then lower the compression ratio until audible firing stopped. This method gave trouble because of difficulty in standardizing operating-temperature conditions and also from carbonization and poor combustion as a result of wide variations in compression ratio. After a large amount of work was done in trying to overcome these difficulties, the method was abandoned.

It was then decided to use the engine without operating it under power. The jacket temperature, air-inlet temperature and engine speed are all under control. This setup thus gives a simple temperature-time

It is interesting to note that the low-ignition Diesel fuels permit a Diesel compression ratio in the same range of compression ratios as present Otto-cycle engines operating on high-ignition-temperature fuels. This leads to a further observation that, should there ever be a volume demand for Diesel fuels comparable with that for carbureter fuels, a general division of the fuel supply could be very advantageously arranged. All high-ignition-temperature fuels could then be disposed of to carbureter engines, and all low-ignition-temperature fuels would be advantageously used by the Diesel engines; also, Otto and Diesel types would approach each other in their compression-ratio range. Fig. 5 shows the compression pressures over the range of compression ratio for the engine used in these tests.

control of the combustion cycle and can be visualized as a dynamic bomb; as temperature, time, and turbulence effects are all present.

The operating conditions which were selected, after dynamometer tests indicated them to be comparable to normal operating conditions for a brake mean effective pressure of approximately 55 lb. per sq. in., were as follows:

Engine Speed, r.p.m.	600
Jacket Temperature, deg. fahr.	210
Air-Inlet Temperature, deg. fahr.	100
Oil Temperature, deg. fahr.	130
Injection Pressure, lb. per sq. in.	1000
Injection Advance Angle, deg.	12
Quantity of Fuel Injected, cc.	0.023

In making a compression-ratio determination for a fuel, the foregoing conditions are obtained and the critical compression ratio is then selected at which audible combustion can be brought in or eliminated by a movement of the cylinder height of one turn of the crank, or 0.007 in. The critical compression ratio is then considered as the mean between the ratio at which firing can be brought in and that at which it is eliminated. Intervals of 1 min. are allowed for stabilization of temperature after moving the cylinder before taking a reading. The injector by-pass valve is then closed for 3 sec. If an audible combustion is heard at the exhaust within this time, the ratio is lowered, and observations are repated until a 0.007-in. movement of the cylinder up or down removes or brings in audible combustion at the exhaust. It is important that the interval of injection be regulated, as the longer it is prolonged the more likely combustion is to occur. Recognition of this fact was essential to the success of this method.

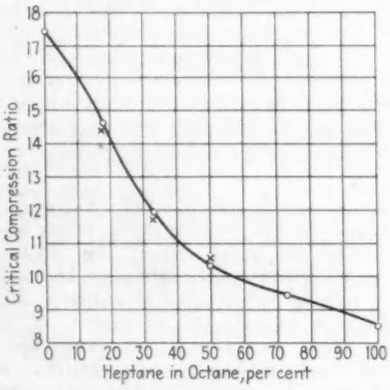


FIG. 4—CRITICAL COMPRESSION RATIOS FOR HEPTANE-OCTANE BLENDS
Points Marked X Are Reference Gasolines, Plotted against Their Carbureter Ratings

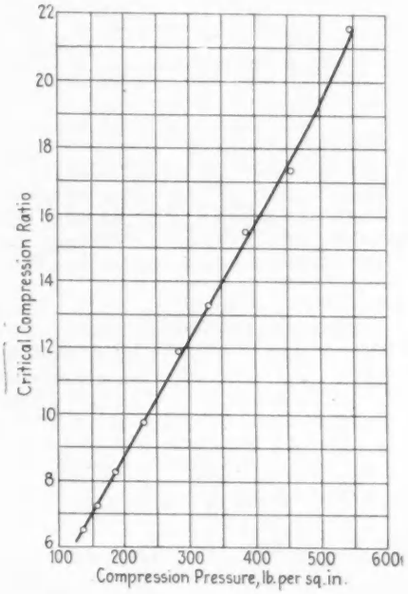


FIG. 5—PRESSURE CURVE FOR VARIABLE-COMPRESSION ENGINE AT 600 R.P.M.

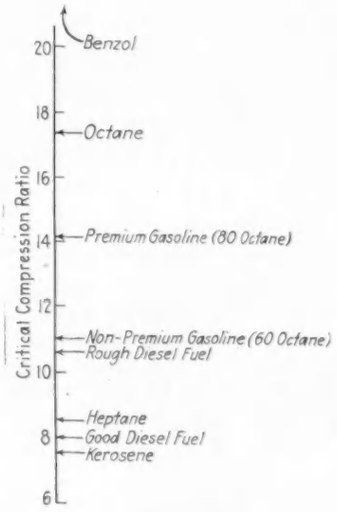


FIG. 6—SCALE OF CRITICAL COMPRESSION RATIOS OF VARIOUS FUELS

General Observations

The data obtained during these tests have suggested an explanation of the phenomena regarding relative changes in ratings on both carbureter and Diesel fuels when tested under different operating conditions. Fig. 9 represents a series of eight Diesel-oil samples tested at two different inlet-temperatures. When tested at 100-deg. inlet temperature, fuels 2 and 3 and fuels 6 and 7 were reversed in order as compared with their order at room temperature. Fig. 10 shows the influence of inlet-air temperature on the critical-compression-ratio rating of a kerosene.

Fig. 11 is a diagrammatic chart of the temperature-time conditions existing in the combustion chamber when obtaining a critical compression ratio for two fuels which match each other at inlet temperature t_1, but which do not match each other at a higher inlet temperature t_2. The area under the full line between the beginning of injection and the opening of the exhaust-valve represents the temperature-time effect available for starting combustion of the fuel when the inlet temperature is t_1. It is assumed that the two fuels match at this inlet temperature; therefore, they are both ignited when subject to this temperature-time influence.

When the inlet temperature is raised, the two fuels require different compression ratios to cause combustion. One fuel permits lowering the ratio more than the other. The new temperature diagrams are indicated by the broken lines. They both have peak temperatures lower than at the original setting, but the reduction in peak temperature is made up by greater total area under the curves because of the higher temperatures near the end of the stroke. It becomes apparent from these new areas that one fuel must be more responsive to temperature peak while the other is more responsive to temperature time, presumably because of difference in molecular structure. In other words, one fuel is more critical to intensity of heat and the other to quantity of heat.

In conclusion, we wish to point out that only a start has been made on the problem of testing injection-engine fuels. Many questions remain in our minds, but the results to date are very encouraging. It is hoped that other laboratories will take up the work in the same cooperative spirit which has been so successful with the development of the Cooperative-Fuel-Research octane rating for gasoline and will thus carry to a rapid completion the problem of rating fuel for the injection-engine.

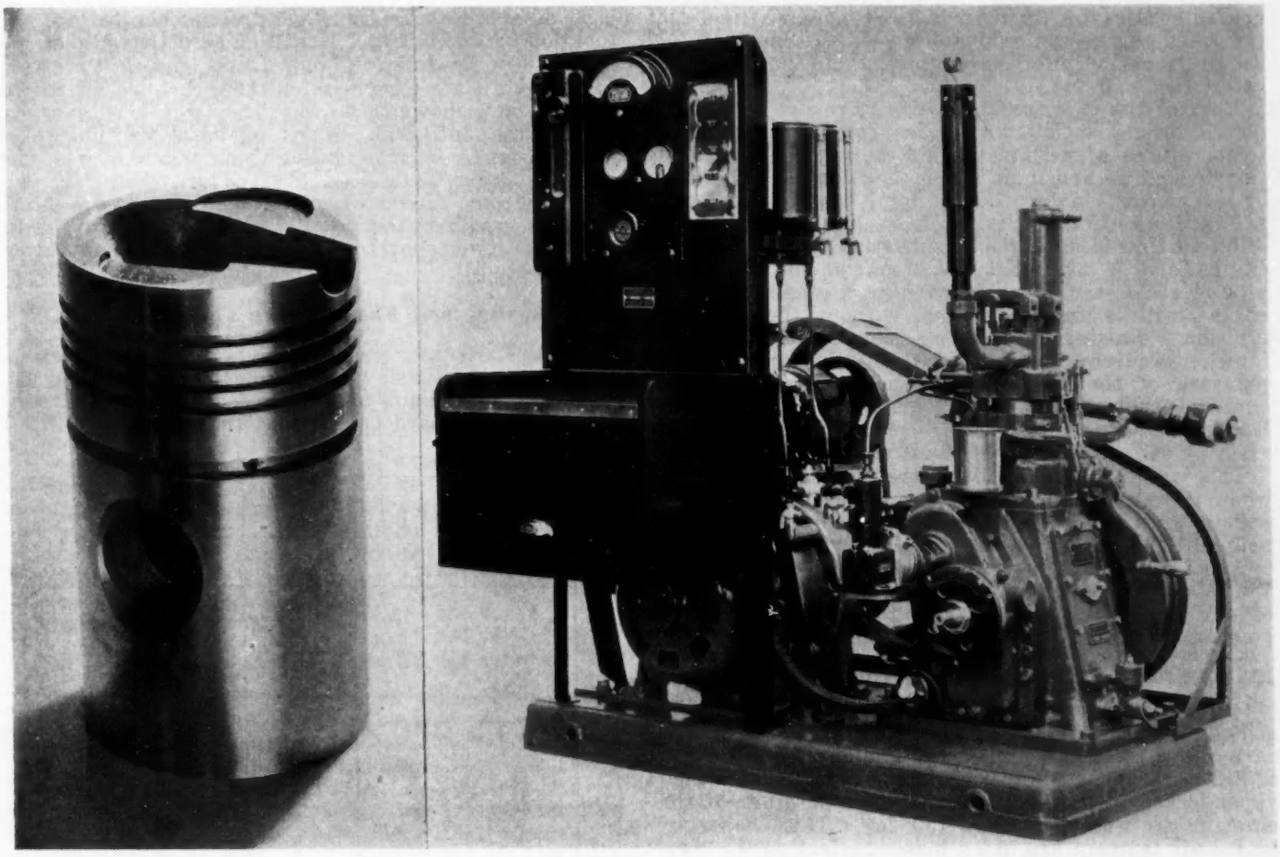


FIG. 7—DIESEL PISTON USED IN C.F.R. ENGINE

FIG. 8—C.F.R. ENGINE AS FITTED FOR DIESEL-FUEL TESTS

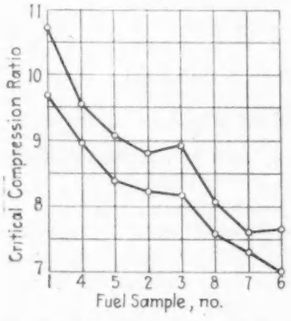


FIG. 9—RATINGS OF EIGHT SAMPLES OF FUEL

Lower Curve Shows Ratings with Inlet Air at 100 Deg. Fahr., Upper Curve at 70-76 Deg.

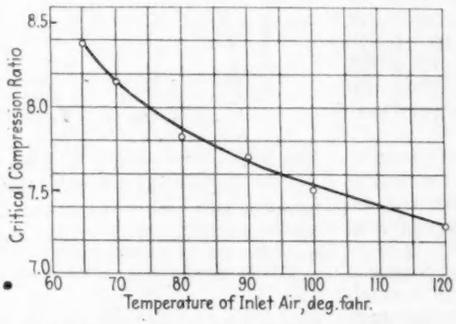


FIG. 10—EFFECT OF INLET-AIR TEMPERATURE ON CRITICAL COMPRESSION RATIO OF KEROSENE

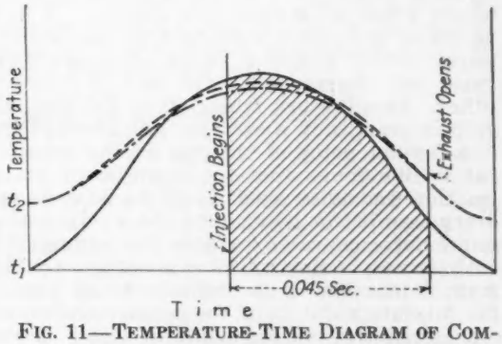


FIG. 11—TEMPERATURE-TIME DIAGRAM OF COMBUSTION PERIOD

Temperature Curves of Critical Compression Ratios Indicating the Characteristics of the Heating Cycles of Two Fuels, Which Match at One Inlet-Air Temperature and Not at a Higher Temperature

THE DISCUSSION

CHAIRMAN O. D. TREIBER[5]:—Some time ago committees were formed in both the S.A.E. and A.S.M.E. to study Diesel fuels. Their plans involved expensive research work, and the two committees were brought together into a joint fuel-research committee. The work of Mr. Pope and Mr. Murdock along this line will be of tremendous value to the industry.

NEIL MACCOULL[6]:—I congratulate Mr. Pope and Mr. Murdock on the work they have done. They have supplied us with a means of finding information that we have all been looking forward to for some time. I wish to add also my appreciation for the wonderfully versatile C.F.R. engine on which they have done their work. This engine has just begun to fill the pressing need of carbureter engines for evaluation of the anti-knock

[5] M.S.A.E.—Chief engineer, Diesel division, Hercules Motors Corp., Canton, Ohio.

[6] M.S.A.E.—Automotive engineer, Texas Co., New York City.

characteristics of their fuels; and now we find that the same engine can evaluate the most important fuel requirements of injection engines, their ignition characteristics.

Back of the experiments I wish to report here was a desire to get satisfactory measurements of ignition temperatures of gasoline under the combustion conditions which we find in an automobile engine. The more or less conventional method of doing this, by bomb, was subject to several faults, such as having an entirely different time element than combustion in an automobile engine and a somewhat questionable control of the mixing ratio. So we tried running a standard C.F.R. engine with a carbureter but without the electrical ignition. Raising the compression ratio until preignition occurred gave a measure of the ignition temperature of the gasoline. In such a device we had similar turbulence and time elements to those of a regular engine, and we had close control of the mixture ratio by the adjustment of the carbureter.

This was tried out and we were pleased to find that, when the compression ratio was raised, the point at which ignition occurred was extraordinarily pronounced; there was no questionable border-line, such as is found in determining anti-knock values by audibility. We found that, after we had developed a few elements of our technique, we were able to check the ignition point on any fuel within 0.05 of a compression ratio.

Temperature of Entering Air

One of the first elements which it was necessary to control was the temperature of the air entering the carbureter. Both air and jacket temperature were run at 212 deg. fahr. at first, but, since many gasolines then vapor locked in the carbureter, the temperature of the entering air was reduced to 150 deg. This change of intake-air temperature had a marked effect on the compression ratio at which ignition would begin. Reducing the intake-air temperature for one fuel from 200 to 100 deg. changed the compression ratio for autoignition from 6.5:1 to 7.8:1, which is a difference of about 0.013 of a ratio per degree. It is interesting to check this value with that given in Fig. 10 of the paper, which shows a range of about 0.010 to 0.032 ratio per degree from one end of the curve to the other. In our work from 100 to 212 deg., the relationship is practically a straight line throughout.

A second point of interest is the effect of mixture ratio. We found that the compression ratio for autoignition was quite sensitive to the mixture ratio; but in every case it was possible to find a mixture ratio giving minimum compression ratio for autoignition, apparently corresponding to the ratio which would give maximum detonation in an engine. In all cases we varied the mixture ratio until we reached that minimum and considered that as the point in which we were interested. We then plotted these autoignition compression ratios for several gasolines against the octane numbers obtained by the ordinary anti-knock methods. These values, shown in Fig. 12, indicate the very interesting agreement secured. Point 1, at the bottom of the chart, represents a certain Pennsylvania gasoline. Points 3, 4, 5 and 6, on the straight line at the left, represent No. 1 gasoline with various additions of tetraethyl lead. Points 7, 8, 10 and 12, on the curve at the right, represent the same No. 1 gasoline blended with various proportions of benzol.

Other points on the right-hand curve of Fig. 12 represent quite a variety of gasolines, including straight-run gasolines, moderately cracked gasolines, vapor-cracked gasolines and California aviation gasolines. Letters *A* and *B* indicate the reference fuels which are used as subreference gasolines by members of the detonation subcommittee. It will be seen that all excepting the lead mixtures fall on a fairly smooth curve.

Apparently we have accomplished what we set out to do. We have shown that a very close relationship exists betwen the antiknock values of gasolines and their spontaneous-ignition or autoignition temperatures, the only exception being lead blends, for which we may later find some reason. I commend to all who are interested in gasolines the possibility of running a C.F.R. engine with a carbureter, as we have done; it is a very fruitful study.

Gasoline and Fuel Oil Are Complimentary

DR. A. E. BECKER[7]:—The authors are to be congratulated for their work, which points the way in the development of fuel oils for high-speed automotive Diesel engines. They have pointed out that the autoignition

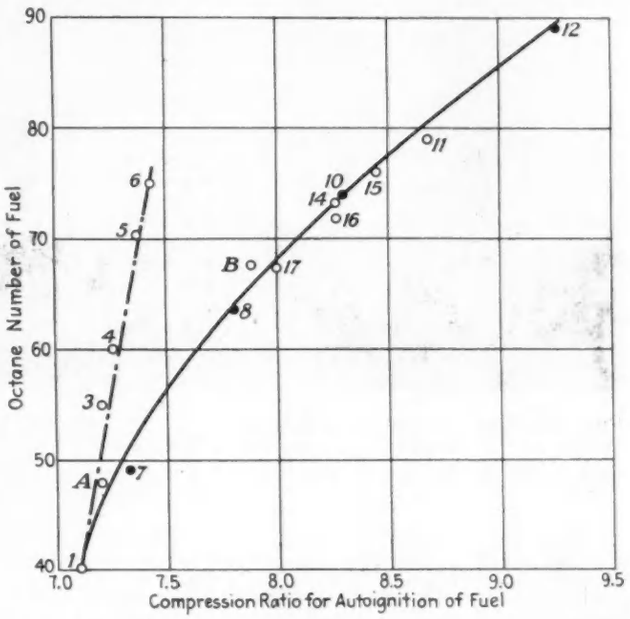


FIG. 12—COMPRESSION RATIOS REQUIRED FOR AUTO-IGNITION OF GASOLINES OF VARIOUS OCTANE RATINGS

Points 3, 4, 5 and 6 Represent the Same Gasolines as Point 1, with Various Additions of Tetraethyl Lead. Points 7, 8, 10 and 12 Refer to the Same, Blended with Benzol. *A* and *B* Are Reference Fuels, and Other Points Are for Various Gasolines

temperature of a Diesel fuel is just as significant as is the antiknock quality of a fuel intended for use in a carbureter engine.

Their observation that Diesel and carbureter engines are complementary in their use of fuels is particularly timely. Their work verifies the contention that fuels of low antiknock quality are required for high-speed Diesel engines, while the present trend toward high compression requires the use of gasolines of high octane number for carbureter engines. This point alone is sufficient to show that Diesel fuels will need to be developed and manufactured just as carefully as gasolines are today. Just any old fuel oil or crude will not suffice. The hopeful thing is that improvement in Diesel fuels also benefits the gasoline situation, in that the very produts which are most difficult to handle for the latter service are the most satisfactory for the former. Thus both types of engine can develop toward higher compression ratios and consequent higher efficiencies.

[7] M.S.A.E.—Standard Oil Development Co., New York City.

The test method employed and its reproducibility are also highly interesting, particularly since the order given for the eight fuels of Fig. 9 is in general agreement with their serial numbers previously assigned from chemical considerations and service tests as being the general order of merit of the several fuels. The additional fact that several gasolines have been tested by this method and the data found to correlate so well with their octane-number ratings by the carbureter engine is most significant, as is also the effect of change in temperature of the inlet air.

A. L. BEALL[8]:—This probably is the first fundamental work that has been done on the ignition temperatures of fuel since the development of the Tausz and Schultz bomb. It is important because of its dynamic characteristics, which relate the ignition temperature directly to the work of the engine. The engine is not necessarily of conventional design; it is a reference device that can be used by both the fuel refiner and the engine designer to determine the characteristics of the fuel and of the engine.

We have known for some years that it is practicable to blend with kerosene to improve the quality of rough-running Diesel fuels, but until this work was done there had been no quantitative information. While this work is only preliminary, it certainly points the way to what can be done, and I wish to appeal for support of the program of the S.A.E.-A.S.M.E. Cooperative Diesel-Fuel-Research Committee.

Time Affects Autoignition Temperature

DR. H. C. DICKINSON[9]:—The problem of Diesel engines and Diesel fuels is one about which we at the Bureau of Standards have been thinking for quite a long time, and it looks as if we ought to do something about it. Engineers not having had all the success they have hoped for in injecting Diesel fuels, they have begun to inject gasolines, with interesting results. In my own division at the Bureau of Standards, two sections are vitally interested in ignition temperature. One is the fire-resistance section, whose problems deal with fire hazards and fire protection. This section is interested in the temperature at which things will ignite if they are heated for long periods. That is a problem more or less by itself. When a wad of oily waste, for instance, is heated, a certain amount of oxygen percolates through this mass and, if the oil happens to be one that is oxidizable, it oxidizes slowly. The waste is a very good heat insulator, and most of the heat formed by the initial oxidation in the mass is accumulated there. A slow building up of temperature thus occurs, which may culminate in a fire after a time of anywhere from 15 min. to 15 weeks. It may take months for the same thing to occur in a coal pile. In Diesel engines we are not interested in that kind of ignition temperature, but in what happens in a small fraction of a second, and there has been a lot of more or less random discussion as to where the two come together. Most of the methods which have been employed for giving figures purporting to represent the ignition temperatures of various things have been based on tests which involved times too short for one purpose and too long for the other, and the ignition temperatures obviously vary enormously with the times.

There has been some discussion among various groups, including our own staff, as to whether or not it is possible to measure an ignition temperature when ignition occurs in less than 0.01 sec., or even 0.001 sec., and have the result hold true for ignition that occurs only at the end of a week. In fact, we have had a lot of hypothetical arguments as to whether there is such a thing as an actual ignition temperature which is purely a function of the fuel itself. I don't know whether there is or not. We haven't been able to satisfy ourselves. Some of us argue on both sides. But whatever may be the case, The Waukesha company has shown us a way of finding definitely the thing we want to know. We are not so much interested in the theoretical question as to whether or not there would be some definite ignition temperature if the time were absolutely zero.

How Alcohol Can Be Burned

L. F. BURGER[10]:—A serious question in connection with Diesel engines is the possibility of burning alcohol, which is so plentiful and cheap in some countries, notably South America, that there is a desire to mix say 40 to 50 per cent of it with fuel oil. We have been unable to find a mineral oil from which alcohol will not separate within a few minutes after the mixture has been made, although it will mix with some vegetable oils fairly well. We must not limit ourselves to this Country in the sale of Diesel engines. What is the solution of this problem?

H. L. HORNING[11]:—Alcohol is very low in heat value, and the heat required for vaporization is such that it cools the combustion chamber very much. Methyl alcohol was mixed in the fuel usel in the Snyder Cup Race to keep the combustion chamber cool.

Mixtures of petroleum fuels and alcohol can be made by the addition of small quantities of acetone. However, if alcohol is to be used, it may be necessary to start combustion with some fuel like kerosene.

K. J. DEJUHASZ[12]:—Before we go far in this research, we must decide the amount of turbulence and the kind of spray that are to be used, because both of these influence the compression ratio at which spontaneous ignition will occur. I suggest that the turbulence be made as little as possible, because this is the easiest condition to attain. A quiescent combustion chamber would seem to be the most suitable.

Autoignition Tests of Gasoline

E. T. VINCENT[13]:—This paper is of great interest and requires a lot of study to appreciate at its full value. Much information was collected and published in England on the various phases of combustion before the recent work of Ricardo, and this is well worth study when considering the roughness or otherwise of combustion.

The authors' indicator diagrams indicate that a pencil-type indicator was used for obtaining them. If this is so, it is rather unfortunate, since such an instrument is very unreliable even at 600 r.p.m. and when handled most carefully. Conclusions drawn from these diagrams must suffer accordingly.

It is my experience that the type of injection system influences the combustion characteristics considerably; therefore, for a complete picture of the problems involved, experiments should be performed with both high and low-pressure systems. The injection for a low-pressure system for a 1000-r.p.m. engine would be timed about 20 deg. before top center to secure maximum pressure at about 10 deg. after top center, while a high-pressure system would be timed about 5 deg. before top center to secure the same result with the same compression ratio. This illustrates the great variation in combustion characteristics, whereby a fuel that is rough for low-pressure injection may be a smooth when in-

[8] M.S.A.E.—Engineer, Vacuum Oil Co., New York City.

[9] M.S.A.E.—Chief, heat and power division, Bureau of Standards, City of Washington.

[10] M.S.A.E.—Chief engineer, International Harvester Co., Chicago.

[11] M.S.A.E.—President, general manager, Waukesha Motor Co., Waukesha, Wis.

[12] Assistant professor of engineering research, The Penn State College, State College, Pa.

[13] Continental Motors Corp., Detroit, Mich.

jected at high pressure. Experiments therefore seem to be necessary with both systems to determine whether the fuels grade themselves in the same order whatever the injection characteristics.

It is feared that too much work on fuels before the engine side of the problem is advanced sufficiently will result in special fuels of high cost, whereby the major advantage of the Diesel engine will be lost. Let us push forward such researches as that under discussion, by all means; the information gathered is of great value. But do not use it to overcome defects in injection and combustion control with normal fuels; work these out as well, so that the engine will run on cheap, common fuels. The maximum advantage as regards power output and speed can then be secured from the use of such special blends as may be found desirable.

HARTE COOKE[14]:—Mr. Pope and Mr. Murdock and the company with which they are connected are to be complimented upon their broadmindedness in presenting this paper. It is desirable that others in the industry cooperate to carry on this research, and the company with which I am connected is willing to participate in this.

Reference Fuels Suggested

T. B. RENDEL[15]:—Mr. Pope has mentioned Mr. Boerlage and Mr. Broeze, who are working in Europe along very similiar lines to develop a test for the ignition quality of Diesel fuels, as it was early realized in connection with a general research program on Diesel fuels that ignition quality is one of the most important factors. In their work they have used a 20 H.P. Thomassen direct-injection engine running at about 600 r.p.m., which was fitted with a special type of throttle to vary the compression pressure. A Maihak indicator was used, which was specially fitted so that the exact point of the beginning of fuel injection could be recorded, together with the pressure rise during the combustion period. Tests were carried out by noting the difference in delay period for two different compression pressures, the delay period being defined as the interval between the beginning of injection and the beginning of the abrupt rate of pressure rise.

As in the case of knock-rating determinations on gasoline, it was decided that the ignition qualities of Diesel fuels were expressed better in terms of two reference fuels than in terms of some engine characteristic. Boerlage and Broeze suggested for such use cetene and mesitylene; cetene being a paraffin hydrocarbon which gives very smooth-running in an engine, while mesitylene belongs to the aromatic group and is worse than any fuel tested so far at their laboratory. The proportions of a blend of these fuels which gives the same difference in delay period for the same two compression pressures is used to express the ignition quality of the fuel under test. Results are reported as cetene numbers; the higher the cetene number, the better the fuel.

Diesel fuels from American crudes vary from about 68 to 40 cetene number. A great deal of correlation work on the importance of ignition quality in actual service has been carried out, and it has been found that the cetene numbers required in practice for European engines vary from 55 for the better class of engine with good combustion-chamber characteristics, to 64 for the poorer class of high-speed direct-injection engine.

[14] M.S.A.E.—Mechanical engineer, McIntosh & Seymour Corp., Auburn, N. Y.

[15] M.S.A.E.—Motor testing research engineer, Shell Petroleum Corp., St. Louis.

Automobile Fuel-System Design

(*Concluded from p.* 135)

lock may occur in the jets. Further, if the vent on the carbureter float bowl is not very large, pressure may be built up in the bowl, with the result that the engine may stop due to overrichness of the mixture. Change of mixture ratio in this direction is probably one of the major causes for engine stoppage during idling under conditions where the fuel has been heated practically to the vapor-locking temperature in the fuel-pump.

While comparatively little attention has been paid to the carbureter in its relation to vapor lock, increased size of vent on the float bowl and means for separating the vapor from the liquid have been found to be effective in solving some idling difficulties. Whereas a much more satisfactory method of solving the carbureter difficulties is to keep the fuel cooler by better design and installation of the fuel system, it is probable that there will be an increase in the occurrence of trouble in the carbureter if pressure-feed systems come into more extensive use without decrease in the fuel temperature. The possibility of vapor lock in the carbureter therefore makes it desirable to place greater emphasis on decrease in fuel-line temperatures than on increase in pressures.

Welding in All-Steel Body Production

10th National Production Meeting Paper

By Joseph W. Meadowcroft[1] and James J. Paugh[2]

ALL-STEEL welded bodies for passenger-cars have many advantages over composite bodies, among them being fewer parts, doors of only two pieces, no visible outside seams, lower tops for the same headroom, less roof weight, lower center of gravity, greater safety, increased visibility, permanent quiet, economical upkeep and perfect outside lines. Wood and steel react so differently to stress that neither adds much to the strength of the other in a composite structure. Steel alone, welded into a unit structure, is lighter and less bulky. The entire side of the body is stamped from a single sheet, with the openings die formed to reenforce it. Chassis frame and body follow the same lines, so that they reenforce each other and body sills can be omitted. This plan saves 2 in. in height, as compared with some other bodies.

Flash welding is employed to join sheets 120 in. long and of any desired width, because mills are not equipped to produce, economically and speedily, sheets of the required accuracy. The tonneau rear seams are flash welded also, and the cowl and roof are attached by spot welding. Flash welding of the larger sheets requires uncommonly accurate alignment of the edges of the metal due to the scarfing operation which trims both sides of the weld in one operation. Magnetic clamping allows perfect alignment since the pressure is self-contained. Handling the large units for welding small reenforcements like those for hinges, locks and fender bolts can only be accomplished on a spot-welding machine of great flexibility, used in conjunction with overhead carrying equipment. Electrodes are important; most of them are of hard-drawn copper or a material that contains a large percentage of copper. To secure long life, electrodes are cooled to within ½ in. of their points wherever possible.

The automobile body really is a container designed for transportation purposes. It must have a certain capacity, must be strong and serviceable, must possess certain conveniences and must meet the requirements of appearance. In the all-steel body, the necessary skin or shell is utilized as the chief structural member and reenforced by additional strengthening members wherever needed. In a sedan are found 2303 spot welds and 140 in. of flash welding, plus the welding of the open sheets.

Various applications of welding and the different methods are covered in the discussion, special emphasis being laid on the ductility of the metal in the weld. The welding of thin sheet metal is also considered. Relative tensile strengths of the weld and the parent metal are mentioned, as well as the point at which a weld ruptures. In this connection one member suggests testing the parent metal before welding and comparing the results with those obtained from the welded piece to show the effect of welding upon the metal.

LITTLE has been published on the fabrication of sheet-metal parts, while very much has been published on the fabrication of buildings, the manufacture of machine parts, using the rough rolled tank plate as a foundation, and similar applications. In building operations, volume production does not enter and we are correct in saying that operation work applies to the schedule rather than to the production item. The manufacture of machine parts is also an operation item, as each part must be produced individually. In this paper we will consider welding as a production tool that is used in the manufacture of automobile bodies.

The automobile body is rather important from the production angle today when we consider the production required yearly to satisfy our domestic and foreign requirements. We will deal in this paper with the newest and most unique development in the production of the all-steel automobile body, the unit arrangement, and the simplicity of final assembly to which this product has been brought. The automobile body lends itself very readily to all methods of welding and this all-steel construction offers advantages, such as less weight, greater strength and fewer parts. No comparison will be made between the all-steel construction and the composite design using wood as a strength interior medium, as the former has doors of only two pieces, no outside seams, a lower body that possesses more headroom and is roomier throughout, increased visibility, less roof weight, lower center of gravity, greater roadability, less danger of skidding, safety, permanent quiet, economical upkeep and, above all, perfect lines for the outside.

The present all-steel body is absolutely new in conception. It marks a long step forward in modern coach building and is, we believe, years ahead of anything else. The unit method of assembly permits all welding to be accomplished by handling the various sections of the body as one major part thereof.

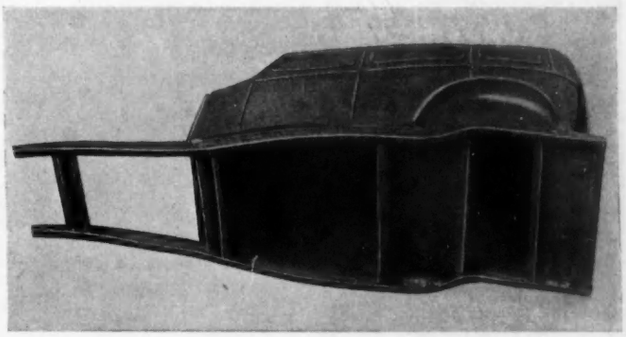


FIG. 1—THE BODY OF THE ALL-STEEL CAR IS FASTENED TO THE CHASSIS WITH BOLTS

In This Design the Side Rails of the Chassis Follow the Contour of the Body, Making the Two Parts Mutually Supporting and Flexible

[1] Assistant works manager, Edward G. Budd Mfg. Co., Philadelphia.

[2] Welding engineer, Edward G. Budd Mfg. Co., Philadelphia.

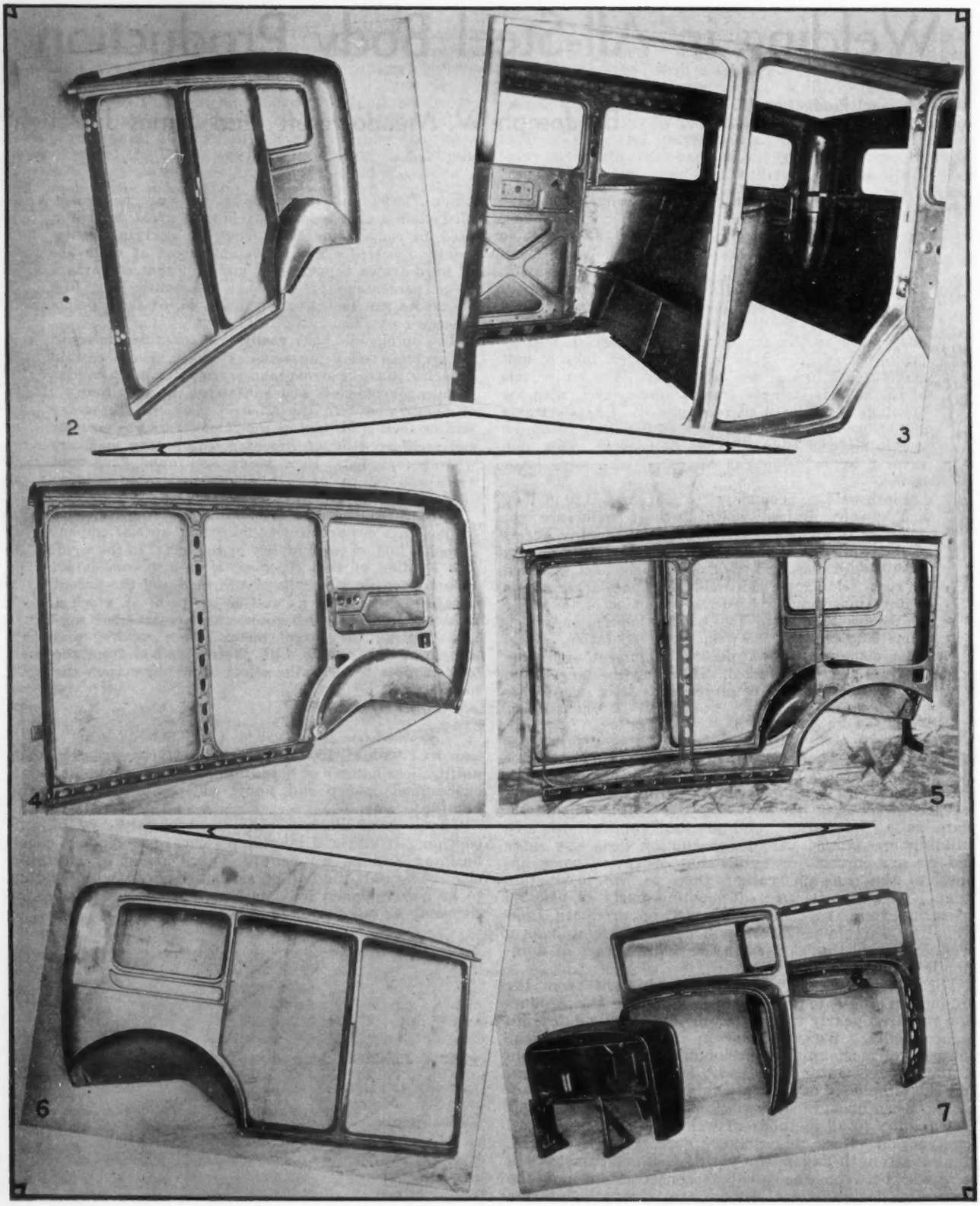


Fig. 2—Inside View of the Stamping for the Side Panel

Fig. 3—Units Assembled into a Complete All-Steel Body

Fig. 4—Stampings for Side Panel after Being Welded Together

Fig. 5—Side-Panel Stampings before Assembly

Fig. 6—Outside View of the Stamping for the Side Panel

Fig. 7—Various Units Forming a Complete Cowl Assembly

SOME TYPICAL STAMPINGS USED IN CONSTRUCTING THE ALL-STEEL BODY

If we study this development closely, we find that the body sills have been eliminated. Chassis and body have been designed, in turn, into a complete unit. The body is bolted to the side of the chassis, which follows the contour of the body, as shown in Fig. 1, making the two mutually supporting and flexible. In this case, body engineers and chassis engineers have cooperated to produce a complete car.

Wood and steel are directly opposite in their reaction to the physical laws of resistance. Under stress, wood obeys one law, while steel obeys another. A body that is built of steel in its entirety and welded into a strong unit structure obeys the same physical laws of resistance throughout. This results in lessening the weight and bulk of the old-time construction considerably. If we consider the combination of wood and steel, we find that one adds little to the strength of the other inasmuch as steel and wood do not resist in the same way. With the elimination of wood used in the old-style body, the weight is bound to be lessened, because no useless material remains to add its dead weight to the completed body.

In the production of the larger stampings fewer parts are required to make up the assembly. Fig. 2. which is an inside view of the stamping for the side panel and Fig. 3, which shows the various body parts assembled, bring out this point.

The entire body side is stamped from one huge sheet of steel with the doorways and window openings die formed in such a manner as to reinforce the original strength of the metal. With the door openings die formed in the side panels of the body and the inner door panels produced as a single die-formed stamping, perfect fit and interchangeability must result. The conventional types of welding, such as the flash welding of the tonneau rear seams, the spot welding of the cowl to the post in the front doorways and the joining of the roof panel to the roof line of the cowl, are used to advantage in the final assembly of the units.

The elimination of the body sills permits the body to be brought closer to the ground without any reduction in the headroom. In most cases the headroom actually is 2 in. greater than is found in many other bodies. Being built of sheet steel instead of wood and steel, all posts on this body are made considerably thinner. This, in turn, permits a roomier car throughout and provides increased visibility. No heavy wooden headers or cross bars are necessary to support the roof and to tie the body structure together, as the side walls themselves are strong enough to support the roof. Elimination of weight around the top lowers the center of gravity and results in greater roadability and less danger of skidding or tipping over, which naturally gives a greater feeling of safety.

Welding Important in Entire Assembly

Electric-resistance flash-welding plays a most important part in the advent of the large stamping. Steel mills were not equipped to produce, at a high rate or in an economical manner, the large pieces of automobile-body stock required. This necessitated the design and manufacture of a means for obtaining the required material, and a large machine was designed and constructed to flash weld two sheets of No. 18 gage material, 120 in. long and of any desired width. This afforded an easy and practical means of obtaining large sheets of uniform thickness. This machine electrically clamps the sheets in place, exerting a pressure of approximately 65,000 lb. at the final weld or push-up, and throughout the cycle all of the operations are controlled automatically.

In taking the sheet through the forming operations that follow, we do not question the strength of the weld. The rate of production varies with the number of men who are actually assigned to the assembly line.

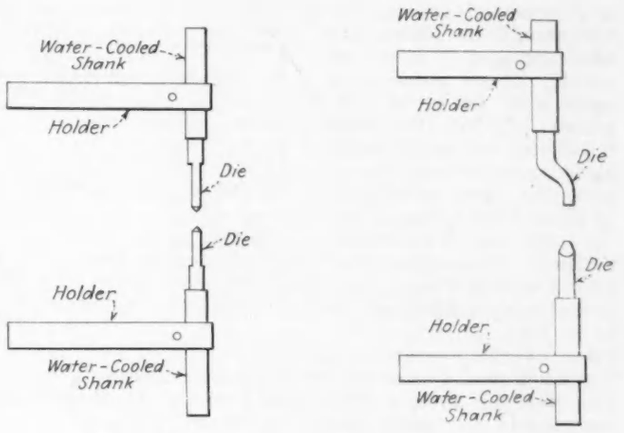


FIG. 8—TWO EXAMPLES OF ELECTRODE SET-UPS

In the design of special equipment of this type, much thought is given to the alignment of the welding dies, as a tolerance of 0.10 to 0.15 in. is usually considered good alignment by present-day welding-equipment manufacturers.

Welding Procedure

The procedure necessary at the start of a new production is vitally important and is laid down primarily by our jig and fixture department which follows closely and body engineering department in the design and assembly of units. From this procedure the entire maintenance forces of the plant lay their plans of operation. Following the issuance of this procedure of operation, the methods and equipment department sets up a proposed draft, considering each operation in sequence. At this point the welding department ties in, having previously contacted with the body engineering and the jig and fixture departments in the application of both new and old welding methods.

With the approved floor draft, a separate welding procedure must be developed from the original procedure, as the copper electrode arrangement is, as a rule, very different for each welding operation, some 5000 arrangements being available. Two of these are illustrated in Fig. 8, and standardization of the electrodes, water shanks and holders prevail throughout in the set-up of the electrodes.

The greatest difficulty in the welding of the new design is in handling the large sub-units during the assembly of such essential small parts as lock reinforcements, fender-bolt tapping-blocks and hinge reinforcements. This could only be accomplished by using a standard spot-welding machine, designed many years ago, with the main thought given to its flexibility. Examples of the use of this horizontal-head machine are given in Fig. 9.

This flexibility permits us to adapt the machine to the stamping. By the installation of proper carriers, conveyed on overhead equipment, we can convey a stamping to the machine and align the working head of the latter so that the large stamping can be worked on with little difficulty in handling. An advantageous point in the selection of flexible spot-welding machines is that they can be operated by hand, foot or power and in a vertical or a horizontal position. The kilovolt-ampere ratings of such machines are very important, and

a substantial safety factor should be allowed in this respect. For example, let us consider a spot weld made on two pieces of No. 30 gage 0.0125-in. material with actual power duration of 0.02 sec. and a similar weld on two pieces of No. 19 gage 0.0437-in. material with actual power duration of 0.079 sec., both welds being performed on a 58 kv-a. normal or 62 kv-a. overload spot-welding machine. The duration of power naturally governs the cost per spot, and in this case the high-powered machine is not costly on the lighter-gage pieces.

In welding the larger sheets, the same flexibility is incorporated in the flash-welding machine, but the entire arrangement is of a rather special nature. The manufacturers of flash-welding equipment today usually consider the alignment of metal edges to within 0.005 to 0.015 in. tolerance as good alignment but this tolerance would be disastrous in the case of large-sheet flash-welding machines. Fig. 10 illustrates why this is so; the removal of the burr or flash metal permits little tolerance, as the scarfing operation trims both the upper and lower burrs of the sheet at the same instant. This perfect alignment is possible only in a machine where the clamping pressure is self-contained and no downward pressure whatsoever is exerted on the great outboard bearings, thus allowing the operating or moving side of the machine to be a freely floating mass. Magnetic clamping of the sheets permits the clamping pressure to be self-contained.

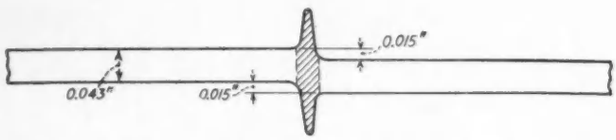


FIG. 10—DIAGRAM ILLUSTRATING THE NEED FOR ACCURATE ALIGNMENT OF MATERIAL IN A LARGE-SHEET FLASH-WELDING MACHINE

If a Tolerance of 0.015 In. Is Permitted in Flash Welding Two Sheets That Are 0.043 In. Thick, the Scarfing Operation, Which Removes the Burr on Each Side of the Sheet, Reduces the Actual Thickness at the Weld to 0.013 In. Which Will Not Permit Die Drawing

Electrodes

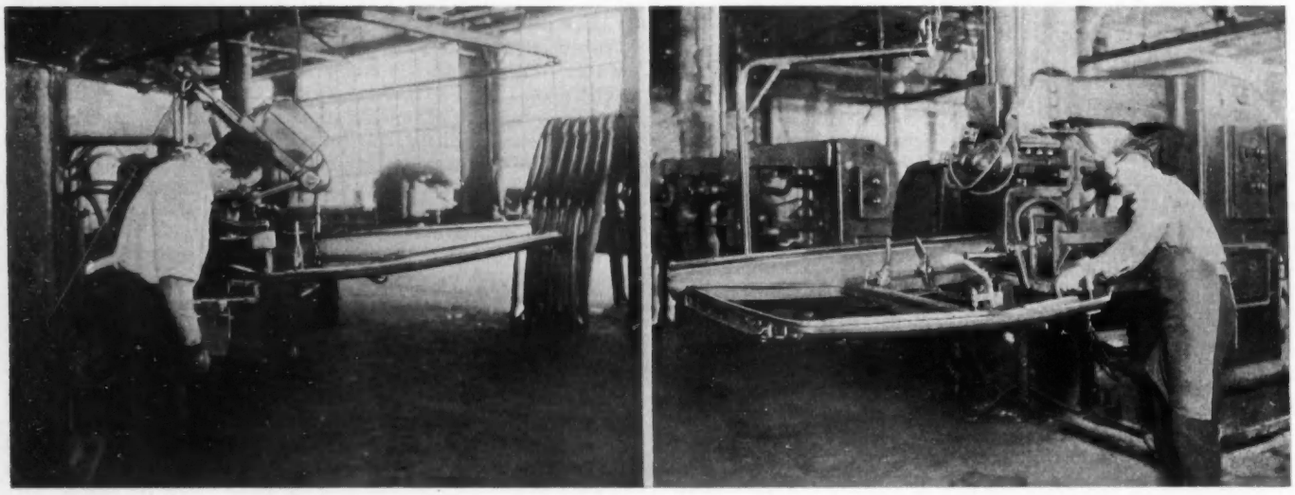
In the application of spot welding in a production line the electrodes are also a very important item. Practically all electrodes are of hard-drawn copper or of some other material high in conductivity, which naturally must contain a large percentage of copper. Materials of high conductivity are desirable, inasmuch as the actual spot-welding operation is performed through resistance and it is not advisable to offer resistance to the power flow until it actually reaches the metals to be welded. In an effort to give the copper used as an electrode a firm foundation, a small percentage of tungsten or cadmium is sometimes used. This provides a soft metal that cannot be expected to be a riveting tool. In any consideration of the electrodes, our first thought is about proper design so that the longest life of the welding point is secured without frequent redressing. Where feasible, all electrode points are cooled to within ½ in. of the working end. The reason for this extreme cooling is that the life of the electrode is shortened considerably if the copper becomes heated intensely.

The next consideration is the service given by electrodes, and to this end we have standardized blanks for all electrodes. As these are produced and manufactured into finished electrodes by our tool division, they very logically are distributed on the production floor through this same medium. This permits electrode service to each floor.

Conclusion

Many items with which the average production manager is never in contact are thoroughly considered by the welding division. These include the heat conductivity of the parts being welded, which is essential in the reduction of small heat lines on the finished outside surface; designing the part to permit easy access of electrodes, which provides longer electrode life, and proper design of equipment for maximum speed and minimum maintenance, which necessitates consideration of stock capacity, proper provision for lubrication, fool-proof pressure devices, adequate cooling, ample electrical-contact surfaces, welding-current switch and control, heat-regulator construction and design and cooling of the transformer.

Because of these items and the fact that the all-steel automobile body depends solely on welding for both strength and quiet operation, the quantity of welding necessary in the complete assembly on one sedan body, 2303 spot welds and 140 in. of flash weld,



Welding Nut Retainer — Welding the Hinge Reinforcement

FIG. 9—TWO APPLICATIONS OF THE HORIZONTAL-HEAD WELDING-MACHINE IN THE PRODUCTION OF THE ALL-STEEL BODY

deserved consideration. This great quantity of welding permits the large stampings to be handled as units that are properly reinforced, as in this construction we do not first build a frame and then attach the metal sheathing to it. The automobile body is really a container designed for transportation purposes. It must have a certain capacity, possess certain conveniences, be strong and serviceable and meet the requirements of appearance. Having all of this in mind, we have a body designed so that the skin, or shell, is the chief structural member. Into this shell additional strengthening members have been introduced at points where they have been needed, and all this has been accomplished with little waste of material. Other reinforcements are placed in carefully selected locations, but only where they are actually needed in view of the fact that the skin is the chief load-carrying member.

The originality in this design lies in the fact that the exterior surface, which must be present in any case, in this instance is made to serve a useful structural purpose, and the chassis side-channel sections, following the shape of the side of the body, offer a union between the body and the frame that is more direct and more rigid than is possible with any other type of body. This body meets the requirements of a satisfactory engineering structure with economy of materials and operations in its manufacture.

THE DISCUSSION

CHAIRMAN J. C. LINCOLN[3]:—My understanding from the paper was that a flash weld was made between the edges of two sheets which were 120 in. long. Was that the method used in making the large sheet? Probably 120 in. would be longer than necessary for any sheet to go into an automobile body, but the width would have to be greater than 30 or 36 in., so that I would expect the weld would be in that direction. How much of the edge of the sheet is flashed off and how much tolerance is allowed between the alignment of these two sheets?

R. W. MILLER[4]:—The clearance between the two sheets before the welding takes place is ⅛ in. and about 3/16 to 7/32 in. on each sheet is taken up in flash.

W. H. GRAVES[5]:—Is my understanding correct that the sheets are welded and scarfed and then put in dies without any worry about the strength of the weld?

MR. MILLER:—That is correct.

JOSEPH GESCHELIN[6]:—Tests along the weld at the Budd plant have never yet shown a failure at the weld itself. Sometimes failure has occurred, but it was in the parent metal itself rather than at the weld line.

Application of Pressure in Welding

PETER FASSLER[7]:—To flash weld successfully two pieces of No. 20 gage sheet steel 120 in. long we must have proper conditions of alignment; that is, ample clamping pressure and an equal volume of metal between the trim line of each sheet and the electrode to which it is clamped. The trimming lines of the sheets should be somewhat tapering so that the flash does not take place along the entire length of the sheet at the same time. For a sheet of this length a taper of approximately 3/16 in. would be required. To flash weld along the entire length of the sheet at one time would require not only an unnecessarily large machine but would lead to the so-called cold or butt weld. If these proper conditions of alignment are obtained, or as we say in the shop, if we develop a flash, we would be able to flash weld this job with a 400-kw. machine. The weld itself should not take more than 200 kw., with a welding time of approximately 4 sec. The welding time can be regulated by the movement of the horizontal slide, which can be operated by air, by hydraulic pressure or by motor. A motor-driven flash welder is preferred, as we can apply the cam principle of operation which gives us a more positive and better controlled welding time.

Butt and flash welding are different even if they do belong to the same class. In making a butt weld, we bring the two pieces to be welded together under pressure before applying the current. This cuts out the flash, because the resistance at the point of contact of the pieces of metal is less. In making a flash weld, we reverse this process and apply the full load of the current before we apply the pressure. We establish very high resistance and a very high localized heat at the point of contact of the metal pieces. This heat brings the metal to a flowing temperature and the resulting flash is this molten metal being discharged. When the metal throughout the entire length of the sheet has reached this temperature, we shut off the current and quickly give the metal a bump. This bump or pushing together of the two sheets completes the weld by upsetting the metal at the weld line while it is still hot. The overlapping of pinholes is our biggest trouble with this type of weld but can easily be overcome by having properly tuned-in electrodes and plenty of clamping pressure to hold the metal securely while it is being bumped. The clamping pressure used for this type of weld will vary from 450 to 650 lb. per sq. in. To create a good starting arc, we arrange the sheets approximately ⅛ in. from each other in the clamps.

CHAIRMAN LINCOLN:—I understood Mr. Fassler to say that the two plates were separated 3/16 or ⅛ in. at one end of the weld and that they touched each other at the opposite end. When the two plates touch, their edges are cold. The heating, starting at this point, goes back 1/16 or ⅛ in. from the edge, increasing the resistance, and crawls along as the two sheets approach each other. This tapered opening decreases the instantaneous power required, as compared with what would be required if the two sheets were parallel. Is that correct?

MR. FASSLER:—Yes.

JOSEPH SUNNEN[8]:—When power at the start of the weld is applied, that produces an arc. Does that arc continue along the sheet, or does the flash occur only when the weld first starts?

MR. FASSLER:—The flash begins at the start of the weld and increases in length until the entire welding line is flashing. When this condition is reached, the current is cut off and the weld completed by the bump. This flash would develop throughout the length of our 120-in. sheet in approximately 4 sec. Of course we can vary the welding time to suit the requirements of any particular job.

MR. SUNNEN:—Is one end of that weld as strong as the other?

MR. FASSLER:—Yes.

[3] Chairman of the board, Lincoln Electric Co., Cleveland.
[4] Superintendent, pressed-steel department, Dodge Bros., Detroit.
[5] M.S.A.E.—Metallurgist, Packard Motor Car Co., Detroit.
[6] M.S.A.E.—Engineering editor, *Automotive Industries*, Philadelphia.
[7] M.S.A.E.—Plant manager, Fisher Body Corp., Detroit.
[8] President, Sunnen Products Co., St. Louis.

CHAIRMAN LINCOLN:—I do not know anything about this flash-welding process, but we have tried to do some development work in arc-welding apparatus. Up to within a year or two the great advantages of resistance welding as compared with arc welding was the fact that to a great extent the resultant weld has the qualities of the parent metal, the ductility and the tensile strength of both being approximately equal, and, when the weld is properly made by this resistance process, the weld will equal the parent metal in its resistance to tension. Up to within a year or two, the weld from the resistance process had high ductility as compared with that made by the arc process.

Those who have worked with arcs know that the tensile strength of an arc weld is entirely satisfactory. To make a weld having a tensile strength approximately equal to that of the parent metal is very easy with bare wires, but in using bare wires to make arc welds the ductility of the weld as compared with that of the parent metal is very different, the former being very much below the latter. Up to within a year or two, the arc-welding process had suffered very materially in that respect as compared with the resistance-welding process. We have been able within the last year or two to eliminate that difference to a very great extent, and we can now make arc welds in which the ductility is approximately equal to that of the parent metal.

The United States Navy has recently bought 24 boiler drums, which were 1¼ or 1½ in. thick. The welds were started at the bottom, and successive layers were applied until finally the weld was completed right to the top. These drums have been tested by the Government and accepted, and are now either in, or being prepared to go into, the battleships.

To be sure that this weld is good, an extra piece is welded to the end of the boiler drum and the weld is continued straight through these test pieces. This is broken off after the weld is completed, and testing coupons are cut out for test. The specifications call for the tensile strength of the welds made in the samples which are cut from this test piece to be equal to the strength of the parent metal. Samples are cut off and the test piece is put into a compression machine and compression is applied so that one side of the weld is stretched. The specifications call for the outside fibers to be stretched at least 30 per cent. With a good weld and a good electrode, from 40 to 45 per cent is very easy to obtain.

The same specifications have been included by the American Society of Mechanical Engineers, through its Boiler Code Committee, for production of boiler drums. The specification for tensile strength is the same and the specification for ductility, the elongation of the outside fiber without breaking, is 30 per cent; so that at present the difference between arc welding and resistance welding is very much less than it was up to the last year or two.

We use two methods of welding. One, in which a carbon arc is employed, we call the electronic tornado process. It is used for production work where a large number of similar samples can be set up. The carbon arc is drawn and a specially prepared paper string is fed down through a copper tube. The rate of feed of the string and the nature of the string itself are arranged so that the atmosphere around the arc is reducing.

Many thousands of experiments have shown that, to get ductile metal with either a carbon or a metallic arc, a powerful reducing atmosphere at the arc is necessary, and furthermore that, with a powerful reducing atmosphere at the arc, metal is obtained which is higher in tensile strength than the parent metal. The necessary thing is that the atmosphere around the arc shall be very strongly reducing, and, when that is so, the metal improves in quality as it passes across the arc, the tensile strength increases and the ductility is approximately 40 per cent.

In welding pipe lines, structural steel and similar work, hand welding with metallic electrodes is the method that must be used. To obtain the desired ductile welds, the original electrode is covered with a coating that produces the reducing atmosphere which is necessary to get the desired results. A metallic-arc weld made with these heavily coated rods has a ductility equal to that obtained with the carbon arc, where a 40 per cent elongation in the bend test is readily obtained.

Welding Thin Material

ARTHUR B. SONNEBORN[9]:—Is that applicable to No. 20 gage material?

CHAIRMAN LINCOLN:—No, up to the present we do not recommend either the carbon-arc or the metallic-arc process for making butt welds in No. 20 gage sheets. We now draw the line from a commercial standpoint at about No. 16 or 18 gage. For thin material, where we can use an edge, a very satisfactory weld is secured. In some cases we make an edge weld by a carbon arc. With an edge weld the material can be as thin as may be desired. Right now we are making a large number of cans from No. 28 gage material having just such an edge weld made with a carbon arc.

For a number of years vessels for cracking gasoline, which are between 30 and 50 ft. long and where the wall thickness many times runs up to 5 or 6 in., have been made by welding either one or two sheets together. Pressures as great as approximately 1000 lb. per sq. in. and at the same time temperatures approaching 1000 deg. fahr. are used in cracking gasoline, and a very extraordinary vessel is required to withstand that combination of very high pressure and temperature. A vessel that will stand this combination can only be made by a welding process, and these welds are made by a welding rod that has a heavy coating and does give the high tensile-strength and the high ductility of which I have spoken. These vessels have been made by the A. O. Smith Corp. for a number of years.

W. W. NICHOLS[10]:—Those vessels are made abroad, and this summer I saw some of them in the Krupp Works and the Skoda Works which were being hollow-forged right from a billet.

CHAIRMAN LINCOLN:—I do not question that the vessels are made out of solid forgings in some places. The A. O. Smith Corp. makes them in the way that I have indicated rather than by hollow forging, probably because it can produce them for considerably less money.

MR. NICHOLS:—The hollow forgings are all bored and turned and are nosed in afterward. A firebrick wall is placed about 7 or 8 ft. back of the nose to keep the heat from traveling down the drum, and then the forgings are nosed in just like a shell.

CHAIRMAN LINCOLN:—That would necessarily be a rather expensive process.

MR. NICHOLS:—It is.

MR. FASSLER:—We have done experimental work in arc welding and have been able to weld No. 20 gage sheet metal just as satisfactorily with the carbon arc as we have with the metallic arc. We are able to weld No. 20 gage sheet metal cleaner and smoother on one side by arc welding than by flash welding. In body work we have to clean up only one side of the welded

[9] Sales manager, Roth Welding Machine Co., Detroit.

[10] M.S.A.E.—Vice-president and mechanical engineer, D. P. Brown & Co., Detroit.

sheets, so in this particular the arc-welding process has the advantage. However, the arc weld is considerably slower than the flash weld, due to its lower power factor. The power factor of the arc weld is only 25 or 28 per cent, as compared with the 85 per cent developed in some instances by resistance-welding machines. If we wish to arc weld No. 20 gage sheet metal we must clamp it similarly to a flash-weld job. The material to be welded must be well clamped down. During our early experimental work we attempted to use copper electrodes but found them too soft. We then switched to Elkonite and achieved considerable success using this material.

CHAIRMAN LINCOLN:—We had difficulty at the factory in welding thin material, and I am very glad to hear that the experience of the Fisher Body Corp. has enabled it to do work that has been rather difficult for us to do at the factory. Our men cannot be as expert in any particular job as the men who are doing similar work in the factory of the user of the machine.

Recent developments in both carbon and metallic-arc welding have made possible a metal in the weld which approaches, in both ductility and tensile strength, the parent metal. This development is so recent that possibly it is not generally known. I rather expect that, as a result of these developments, the arc-welding process will be more of a competitor of the resistance-welding process in many instances where the latter has been used heretofore, because, until within the last year or so, the resistance-welding process had to be used to get ductile metal.

The time required by the flash-welding process will in many cases be less than that required by the arc-welding process, and, frequently but not always, time is the controlling item in the cost. Time is, however, only one item in the cost. The capital cost of the very expensive resistance-welding machines must be considered, and I understand that special generators are required for some of the very large resistance-welding machines. If the capital cost is distributed among all the pieces, which is the only correct way to figure costs, this may equal and in some cases overbalance the saving in time which that method makes possible.

What we are all after is to produce the article that we want to make at the lowest cost. Uptodate the resistance method has been the only one considered, because it alone would give the desired ductile metal, but now the objections to both the carbon-arc and the metallic-arc welding process have been eliminated, and the only question left is the difference in cost of the two processes.

Changes in Metal Structure Produced by Welding

L. K. SNELL[11]:—I would like to hear something about the change in the structure of the parent metal adjacent to the weld, the heat-treatment and its effect. Nothing has been said about that and my experience has been that it is rather important.

CHAIRMAN LINCOLN:—Mr. Snell brings up a very pertinent point. This weld metal has a greater tensile strength than that of the parent metal. He raises the point that some region exists between the weld and the parent metal where any improvement from the action of the arc on the parent metal cannot be effected. This is a matter of theory rather than fact, because, when we make these test samples and pull them, they break outside of the weld.

I will try to give a partial explanation of that. The area of metal along this 45 deg. weld line is roughly 40 per cent greater than the area directly across. If this weld metal is higher in tensile strength than the parent metal, which I think we have demonstrated, at some point between the two that advantage ceases to exist, but where that advantage does cease to exist we have a larger cross-section. That will tend to explain why we are able to drill holes and remove some 25 per cent of this metal before the breaks occur in the weld rather than in the parent metal.

MR. SONNEBORN:—Do those breaks occur just outside the weld?

CHAIRMAN LINCOLN:—In most cases they occur approximately 2 in. outside the weld, or far enough so that this effect which Mr. Snell speaks of does not enter into the question at all. The break will be far enough away from the weld so that any effect of the heat due to the welding operation is entirely eliminated.

MR. FASSLER:—We have a structure change besides, close to the weld, because we change the carbon condition in the metal. We can take care of that if we anneal the weld. Whenever we make an arc weld, we find that it breaks about 1 in. away from the weld and we find this structure change in the parent metal, but the weld is always good.

CHAIRMAN LINCOLN:—If the break occurred 1 in. away from the weld, we would feel that the break occurred from some cause other than the heat effect of the welding operation. We would expect that, if the welding causes any weakening of the parent metal, the break should occur very close to the weld rather than 1 or 2 in. away.

MR. SONNEBORN:—In the majority of the cases where metal has been heated sufficiently to either arc or flash weld it, the break occurs very close to the weld. The same thing occurs in flash welding where all the burned metal is not pushed out or where the dies do not take care of the heat.

Tensile-Strength Test Suggested

ERIK OBERG[12]:—Has the parent metal ever been tested and its strength measured before any weld was made and then tested after the weld was made to see if exactly the same strength remained in the parent metal?

CHAIRMAN LINCOLN:—No. We have assumed that, in a weld where we know that the parent metal has not been heated more than ½ in. from the weld, the metal 2 or 3 in. away where the break occurs has not been affected by the welding operation, and we have not made the particular test that you outline. We have assumed that, if we can remove 25 per cent of the metal by drilling holes through the weld and still get the break outside of the weld, we have demonstrated that the weld metal is superior to the parent metal.

MR. GESCHELIN:—If the cross member of an automobile frame had the joint welded instead of riveted, would the strength at that particular point be reduced?

CHAIRMAN LINCOLN:—Not as far as we know.

MR. GESCHELIN:—There is some question about that.

CHAIRMAN LINCOLN:—I cannot answer that question from experience. The tensile strength of the chassis frame is increased by cold working, and I would suppose that the weld right next to the frame would decrease the strength of that member where the metal is heated. I cannot see how it would be otherwise.

MR. SONNEBORN:—If that is true, why would not it be true of a weld of this nature?

CHAIRMAN LINCOLN:—Because this weld is in metal that has not been cold worked; it is ordinary ¼ or ½-in. sheet steel which was cooled from the rolling process before it was annealed.

MR. GRAVES:—If pressure vessels were made from steel that is stronger than the ordinary low-carbon hot-rolled steel and the manufacturer had to weld it, would

(*Concluded on p.* 152)

[11] M.S.A.E.—Consulting engineer, Detroit.
[12] M.S.A.E.—Editor, *Machinery*, New York City.

Economy of Streamlining the Automobile

THE accompanying material, submitted last June by O. G. Tietjens[1] as written discussion on Herbert Chase's paper, entitled The Case for Rear Engine-Mounting,[2] is an argument for the streamlining of automobiles. The author shows, by means of curves based on tests made by himself on a streamlined automobile model in a wind-tunnel and by tests of wind resistance made by others in this Country and abroad, that from 60 to 84 per cent of the power required to propel a closed car is necessary to overcome air resistance at speeds of 40 to 80 m.p.h. He maintains that, for reasons of economy, streamlining of the automobile is more important than streamlining the airplane fuselage, and in support of this presents curves showing that at a speed of 80 m.p.h. 50 per cent of the total power is required to overcome the air resistance of the fuselage and 84 per cent to overcome that of the present-type closed automobile.

Power savings by suitable streamlining of automobiles, amounting to 50 per cent at 40 m.p.h., 65 per cent at 70 m.p.h. and 70 per cent at 90 m.p.h., are so great that the mileage per gallon at 80 m.p.h. could be tripled and will justify a complete change in the present type of car.

A VERY CLOSE relationship exists between the paper on The Case for Rear Engine-Mounting, presented by Herbert Chase, and the following remarks on streamlining, in that effective streamlining of an automobile is possible only if the engine is mounted in the rear.

When I came to this Country about two years ago to organize the research work on hydrodynamics and aerodynamics for the Westinghouse Electric & Mfg. Co., I soon realized the great importance of faster transportation in this Country. Finding the company closely connected with the railway business, I first worked on the development of new features of the design of electric locomotives, railroad coaches and interurban electric cars. The work was started about 1½ years ago by the building of a special wind-tunnel for testing models of present-type trains as well as those of a streamlined pattern. Also, models of streamlined interurban cars designed for a top speed of 80 m.p.h. were made and tested in this wind-tunnel.

However, I never lost sight of the most important object of streamlining—the automobile. I do not have in mind racing cars or the so-called speedster. Statistics on passenger-car production show that about 70 per cent of all cars built are closed cars for four or more passengers; hence, from a commercial standpoint, only a streamlined body such as that shown in Fig. 1, offering the same ample space and comfort as a sedan, should be considered.

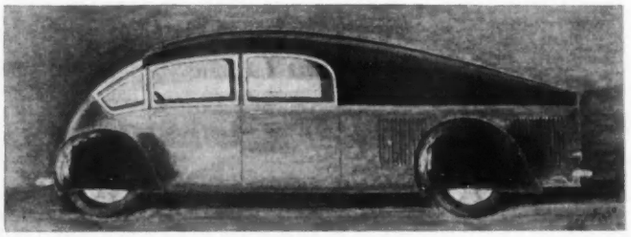


FIG. 1—MODEL OF STREAMLINED AUTOMOBILE HAVING ONLY ONE-FIFTH THE AIR RESISTANCE OF THE PRESENT-TYPE CLOSED CAR

Power Required To Overcome Air Resistance

Although air resistance was an important factor years ago, when the speed on the open road did not exceed 30 or 40 m.p.h., this factor becomes vital nowadays, when the traveling speed often reaches 60 or 70 m.p.h. The power required to overcome air resistance and the power to overcome journal and rolling resistance is shown in Fig. 2 as a function of the speed. A car weight of 3800 lb. and a projected area of 26 sq. ft. are assumed. These curves are based on numerous tests[3] made in this Country and abroad.

A speed of 80 m.p.h., for instance, requires an engine of about 90 hp., of which 14 hp. is required to overcome journal friction and the remaining 76 hp., or 84 per cent of the total power required, is needed to overcome air resistance. The curves show that even at the comparatively low speed of 40 m.p.h. the power required to overcome air resistance is 60 per cent of the total power. This can be reduced considerably by suitable streamlining.

Numerous tests made on models of different shapes have proved that partial streamlining, as the rounding of some corners or sloping the windshield a little more, has only a small effect on the air resistance. If however, the body, wheels and fenders are shaped in accordance with modern aerodynamic knowledge, considerable reduction of air resistance can be obtained. As the result of all my tests, one shape that was finally considered the best has only one-fifth of the air resistance of the present-type car yet offers the same ample space for four or five passengers as does a sedan. This is the model shown in Fig. 1.

At a speed of 80 m.p.h., therefore, only $14 + (76/5) = 30$ hp. is required, instead of $14 + 76 = 90$ hp. for a car of the present shape. The dash line in Fig. 2 refers to a streamlined car, and it is a striking fact that less than 50 hp. is sufficient to obtain a speed of 100 m.p.h. with a streamlined car, whereas more than 160 hp.—that is, more than three times as much power—is necessary to obtain the same speed with the present type. The Duesenberg car is said to deliver 265 hp. and attain a speed of 116 m.p.h. or slightly more. The same speed could be obtained with an engine of only 70 to 80 hp. if the body were perfectly streamlined.

Automobile Streamlining More Important than Airplane-Fuselage Streamlining

Perfect streamlining of a car, or even a close approach to it, is sometimes said to be impractical because air resistance will never be as important a factor with the automobile as with the airplane. Such a statement

[1] In charge of hydrodynamics and aerodynamics, research laboratories, Westinghouse Electric & Mfg. Co., East Pittsburgh, Pa.

[2] Semi-Annual Meeting paper, not published.

[3] See Investigations of Air Resistance on Automobiles, by T. R. Agg and N. Woolfard: Proceedings of the Sixth Annual Meeting, Highway Research Board, 1927; also Wind Resistance of Motor-Vehicles, by L. E. Conrad, *Public Roads*, June, 1925, p. 203; also Air Resistance of Automobiles, by E. H. Lockwood, *American Highways*, August, 1929, p. 1.

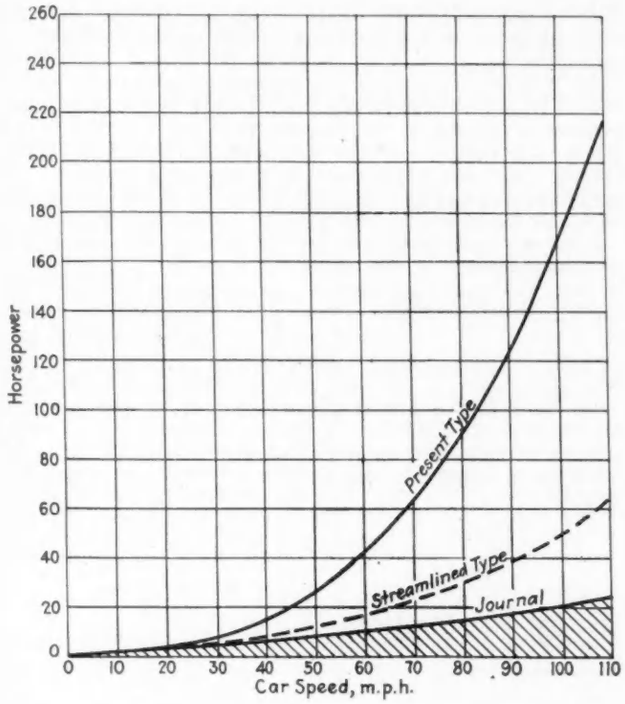


FIG. 2—POWER CONSUMPTION OF AN AUTOMOBILE AS A FUNCTION OF SPEED

The Car Is Assumed to Weigh 3800 Lb. and To Have a Frontal Area of 26 Sq. Ft. The Dash Line Shows the Power Required to Overcome Air Resistance and Journal Friction of a Streamlined Car

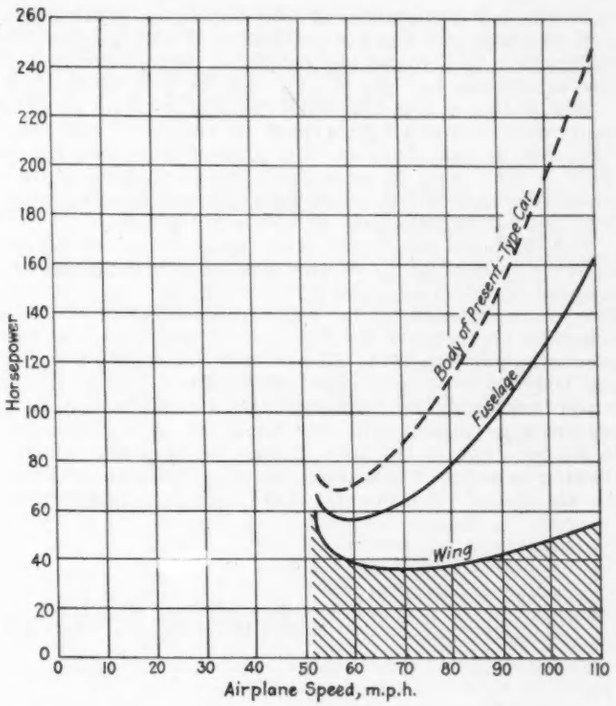


FIG. 3—POWER CONSUMPTION OF AN AIRPLANE AS A FUNCTION OF SPEED

These Curves Are for a Curtiss Four-Passenger Cabin Airplane Having a Wing Area of 290 Sq. Ft. and Weighing 2850 Lb. with Full Load. The Shaded Portion Shows Power Required to Overcome Wing Resistance. The Dash Line Shows Power Needed to Overcome Resistance of Present-Type Closed Automobile Body

shows that the performance of an airplane, and particularly that of an airplane wing, is not well understood. It can be shown that streamlining an automobile is more justified by the possible economy than is streamlining the fuselage of an airplane.

The total resistance of an automobile can be divided into the air resistance and the journal resistance. Similarly, we can separate the total resistance of an airplane

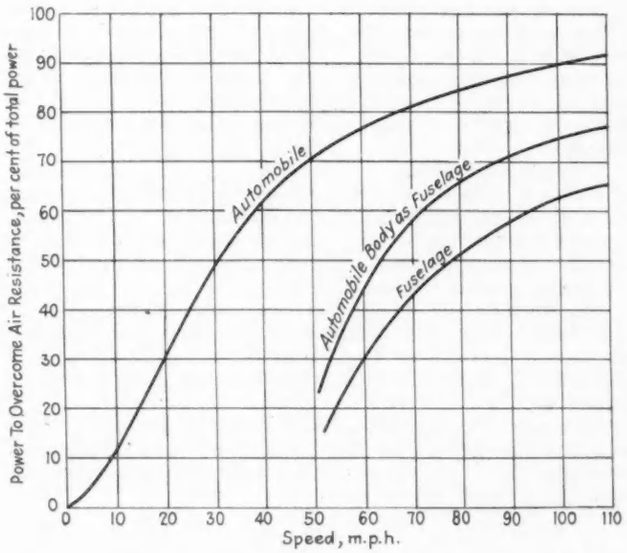


FIG. 4—PERCENTAGES OF TOTAL POWER REQUIRED TO OVERCOME AIR RESISTANCE OF AN AUTOMOBILE, A FUSELAGE AND AN AUTOMOBILE BODY ASSUMED TO BE USED AS A FUSELAGE

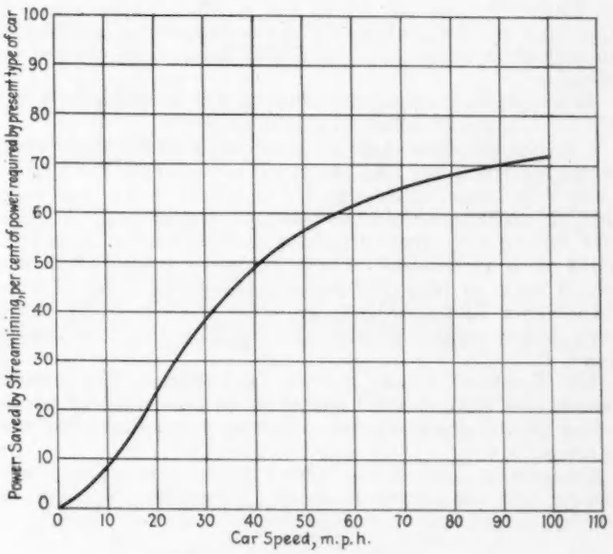


FIG. 5—POWER SAVED BY STREAMLINING AN AUTOMOBILE, IN PERCENTAGE OF POWER REQUIRED FOR PRESENT TYPE OF AUTOMOBILE

The Automobile Is Assumed To Weigh 3800 Lb. and To Have a Frontal Area of 26 Sq. Ft. The Fuselage Is That of a Curtis Four-Passenger Cabin Airplane. The Middle Curve Is for the Automobile Body Applied as the Airplane Fuselage

into the air resistance of the fuselage, landing-gear and so forth and the air resistance of the wings. The latter part is comparable with the journal friction of the automobile.

Fig. 3 shows that the wing resistance of an airplane represents a much larger part of the total resistance than the journal friction of a present-type automobile. This is true even if we replace the fairly well streamlined fuselage of a Curtiss four-passenger cabin plane with an automobile body of the same weight.

Fig. 4 shows the power required to overcome air resistance in percentage of the total power required. At a speed of 80 m.p.h., the power necessary to overcome the air resistance of a well-streamlined fuselage is about 50 per cent of the total power required, and this percentage increases to 66 per cent for a fuselage like the body of a present-type automobile. However, the power necessary to overcome the air resistance of a present-type automobile moving at 80 m.p.h. amounts to 84 per cent of the total power, because the journal friction is so much less than the wing resistance. From the standpoint of economy, therefore, it is more desirable to streamline the body of an automobile than to streamline the same body considered as the fuselage of an airplane.

In Fig. 5 the saving of power by streamlining is shown in percentage of the total power required for the present type of car. It is seen that for a speed of 40 m.p.h. a saving of 50 per cent can be obtained. This saving increases with speed so that, for a speed of 70 m.p.h., 65 per cent of the power may be saved, while for 90 m.p.h. this saving increases to 70 per cent.

Such an enormous saving in power will justify a complete change in the appearance of the present type of car. Whereas a present car at a top speed of 80 m.p.h. consumes 1 gal. of gasoline for about 10 miles, about 30 miles per gallon could be obtained for a car having the same top speed but which is streamlined as in Fig. 1.

I believe that there is no question as to whether the streamlined automobile will be adopted; the only question is, when will it be done and what company will be the first to start the production of such a car of the future?

Welding in All-Steel Body Production

(*Concluded from p.* 149)

not welding reduce the strength of the special steel to such an extent that he would still have to use the same thickness?

CHAIRMAN LINCOLN:—We believe that is not true. Our experience up to the present has been limited very largely to the soft steels, because the market for welding of soft materials is very much greater than for welding of the high tensile-strength steels. From what experiments we have made, we believe that welding alloy steels will present no special difficulty, but we cannot speak confidently on that point from experience. Experience in making sample welds and pulling them so as to get this high tensile strength is the final word. Experimentally we have obtained tensile strengths up to 95,000 lb. per sq. in. in the welds. Those are preliminary results, but we do not anticipate any difficulty in making a nickel-steel weld that is equal to the parent metal.

MR. GRAVES:—Do you think that it is possible without heat-treating after welding?

CHAIRMAN LINCOLN:—Those 24 vessels that were made for the Navy had the temperature raised to about 1200 deg. fahr. and kept there about 1 hr. for each inch of thickness, so that the heat would soak through and relieve any strain that the welding might have left. That is a precaution which is being taken now but which may or may not be necessary years from now. Experience seems to indicate that the strain in these very heavy vessels must be relieved by this heat-treatment.

MR. SNELL:—I take it from this that, in the welded vessels, we cannot avail ourselves of the inherent properties of the steel but have to use the material in the annealed state.

CHAIRMAN LINCOLN:—These boiler drums are annealed and are stress relieved. Whatever increase in tensile strength we get by annealing at 1200 deg. fahr. we have to sacrifice.

MR. GESCHELIN:—What has been your experience in welding rear axles?

CHAIRMAN LINCOLN:—We have welded many thousands.

MR. GESCHELIN:—I saw an axle this week, I imagine it was a nickel-steel tube welded to a drop-forged end, which was pulled and broke in the tube rather than at the junction of the forging and the tube.

MR. OBERG:—I suggest that, to settle some of the doubt that still seems to exist in the minds of several of those here as to exactly where the break happens and why, a tensile test be made on the parent metal before anything has been done to it and then a test of a welded piece and a comparison made of the results. That would be more conclusive and would give a more definite comparison than testing the piece only after it is welded, because then the question comes up, as it has here, of why and how far from the weld the piece breaks.

CHAIRMAN LINCOLN:—I remember somewhat vaguely a number of tests of that nature in which the coupon of the parent metal showed 50,000 lb. per sq. in. as its tensile strength and then the strength of the welded samples was compared with the strength of the coupon from the parent metal.

MR. OBERG:—If the tests have shown definitely that they still retain the same relation, then the question as to whether or not the break occurs near enough to the weld so that the metal has been affected has been answered.

CHAIRMAN LINCOLN:—The answer is definitely that welding does not affect the strength of the parent metal very far from the weld as has been demonstrated by very many repeated tests.

Standardization Progress

Shall Tap Lengths Be Revised?

Sectional Committee Desires Industry's Views on Advisability of Revising Standard

IN 1930 the American Standard B5e, which was formulated by the Sectional Committee on Small Tools and Machine-Tool Elements, sponsored by the Society, the American Society of Mechanical Engineers and the National Machine Tool Builders' Association, was approved by the American Standards Association and has since come into wide use. This standard includes the detail dimensions for machine-screw, hand, tapper and nut taps with both ground and cut threads and pulley taps with cut threads.

Technical Committee No. 12 of the Sectional Committee, which originally drafted the tap standard, has been considering for some time the suggestion by the German National Standards Committee that the over-all lengths and thread lengths for Hand Taps (Table 1) be reduced and has accordingly circulated this suggestion to learn the reaction of American industries to the suggestion.

The proposal is published in this issue of the S.A.E. JOURNAL to give the entire automotive industry an opportunity to express its opinion as to whether this or a similar revision would be desirable. The Society, as one of the sponsors for the Sectional Committee, is responsible jointly with the other sponsors for the standard and solicits the automotive industry's cooperation by responses to the following questions:

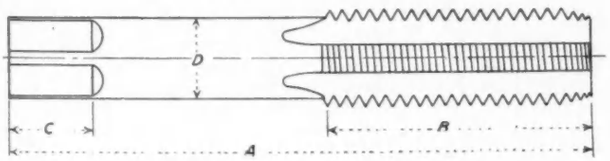
(1) Can the present standard over-all lengths and thread lengths of Hand Taps be reduced to advantage?

(2) Would the suggested reduced lengths shown in accompanying Tables 3 and 4 be acceptable?

(3) If the suggested lengths are not satisfactory, what reduced lengths would be acceptable?

Any changes in the established standard will have an almost universal effect on both the tap makers and users, and only with their cooperation can the Sectional Committee and its sponsors

TABLE 1—STANDARD HAND TAPS



Tap Size, Inches	General Dimensions, In.					
	Over-All Length, *A*	Thread Length, *B*	Square Length, *C*	Shank Diameter, *D*	Square Size	Land Width
1/4-20	2 1/2	1	9/32	0.255	0.191	0.065
1/4-28	2 1/2	1	9/32	0.255	0.191	0.065
5/16-18	2 23/32	1 1/4	5/16	0.318	0.238	0.081
5/16-24	2 23/32	1 1/8	5/16	0.318	0.238	0.081
3/8 16	2 15/16	1 1/4	3/8	0.275[a]	0.206	0.097
3/8-24	2 15/16	1 1/4	3/8	0.381[a]	0.286	0.097
7/16-14	3 5/32	1 7/16	13/32	0.323	0.242	0.114
7/16-20	3 5/32	1 7/16	13/32	0.323	0.242	0.114
1/2-13	3 3/8	1 21/32	7/16	0.367	0.275	0.130
1/2-20	3 3/8	1 21/32	7/16	0.367	0.275	0.130
9/16-12	3 19/32	1 21/32	1/2	0.429	0.322	0.146
9/16-18	3 19/32	1 21/32	1/2	0.429	0.322	0.146
5/8-11	3 13/16	1 13/16	9/16	0.480	0.360	0.162
5/8 18	3 13/16	1 13/16	9/16	0.480	0.360	0.162
3/4-10	4 1/4	2	11/16	0.590	0.442	0.194
3/4-16	4 1/4	2	11/16	0.590	0.442	0.194
7/8- 9	4 11/16	2 7/32	3/4	0.697	0.523	0.212
7/8-14	4 11/16	2 7/32	3/4	0.697	0.523	0.212
1 - 8	5 1/8	2 1/2	13/16	0.800	0.600	0.242
1 -14	5 1/8	2 1/2	13/16	0.800	0.600	0.242
1 1/8- 7	5 7/16	2 9/16	7/8	0.896	0.672	.....
1 1/8-12	5 7/16	2 9/16	7/8	0.896	0.672	.....
1 1/4- 7	5 3/4	2 9/16	1	1.021	0.766	.....
1 1/4-12	5 3/4	2 9/16	1	1.021	0.766	.....
1 1/2- 6	6 3/4	3	1 1/8	1.233	0.925	.....
1 1/2-12	6 3/8	3	1 1/8	1.233	0.925	.....
1 3/4- 5	7	3 3/16	1 1/4	1.430	1.072	.....
2 -4 1/2	7 5/8	3 9/16	1 3/8	1.644	1.233	.....
2 1/4-4 1/2	8 1/4	3 9/16	1 7/16	1.894	1.420	.....
2 1/2- 4	8 3/4	4	1 1/2	2.100	1.575	.....
2 3/4- 4	9 1/4	4	1 9/16	2.350	1.762	.....
3 -3 1/2	9 3/4	4 9/16	1 5/8	2.543	1.907	.....

[a]Optional shank diameters.

TABLE 2—COMPARISON OF GERMAN AND AMERICAN STANDARDS, OVER-ALL AND THREAD LENGTHS FOR HAND TAPS

Tap Size, In.	1/4	1/2	3/4	1	1 1/2	2
Length Over-all, In. (German)	2.165	3.149	3.937	5.118	6.889	8.661
(U. S.)	2.500	3.375	4.250	5.125	6.375	7.625
U. S. Difference	+0.335	+0.226	+0.313	+0.007	−0.514	−1.036
Thread Length, In. (German)	0.984	1.377	1.771	2.362	3.149	3.937
(U. S.)	1.000	1.656	2.000	2.500	3.000	3.562
U. S. Difference	+0.016	+0.279	+0.229	+0.138	−0.149	−0.375

TABLE 3—SUGGESTED METHOD OF FIGURING REDUCED THREAD LENGTHS OF HAND TAPS

Tap Size, In.	Range of Pitches	Suggested Thread Length, In.	Present Thread Length, In.
1/4[a]			15/16	1
5/16	14 (0.0714) to 24 (0.0416)	0.0714x13 =0.9282 or	15/16	1 1/4
1/2	11 (0.0909) to 20 (0.0500)	0.0909x13 =1.1817 or 1	3/16	1 21/32
3/4	9 (0.1111) to 16 (0.0625)	0.1111x13 =1.4443 or 1	7/16	2
1	7 (0.1428) to 14 (0.0718)	0.1428x13 =1.8564 or 1	7/8	2 1/2
1 1/2	5 (0.2000) to 12 (0.0833)	0.2000x13 =2.600 or 2	5/8	3
2	4 (0.2500) to 12 (0.0833)	0.2500x13 =3.250 or 3	1/4	3 9/16

[a]Included in the 5/8-in. group.

TABLE 4—SUGGESTED OVER-ALL LENGTHS OF HAND TAPS AND METHOD OF DERIVING

Tap Size, In.	Over-All Length, In.	Present Ratio, Length, to Size	Suggested Ratio, Length to Size	Suggested Over-All Length, In.
1/4	2 1/2	10 to 1	9 to 1	2 1/4
5/16	2 15/16	8 to 1	7 to 1	2 5/8
1/2	3 3/8	6 3/4 to 1	6 to 1	3
3/4	4 1/4	5 2/3 to 1	5 to 1	3 3/4
1	5 1/8	5 1/8 to 1	4 1/2 to 1	4 1/2
1 1/2	6 3/8	4 1/4 to 1	4 to 1	6
2	7 5/8	3 13/16 to 1	3 1/2 to 1	7

be guided in their action on the suggested modification of tap lengths. Users of taps in the automotive industry are urged to promptly express their views on the suggested change, addressing their replies to the Standards Department of the Society in time for them to be submitted to the Sectional Committee the latter part of March.

Acorn-Nut Standardization

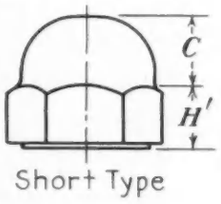
Two Types Proposed by Standards Committee Are Submitted for Industry's Comment

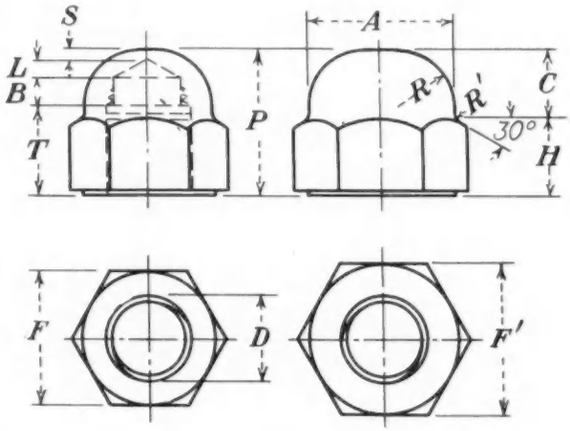
LAST YEAR the Screw-Threads Division of the Standards Committee made a study of the desirability of establishing standard dimensions for what are popularly termed acorn nuts. Data collected from various sources indicated a wide variety of styles and dimensions which have been reduced to two styles in the accompanying report that was submitted at the meeting of the Division in Detroit on Jan. 26.

On account of the limited quantities of nuts of this type that are used, the crown has been designed purposely to give flexibility in application. When the nuts are made of brass, the height of the hexagon may be reduced to three-quarters of the thread diameter or even less, to lighten the appearance, but retaining sufficient strength in the threads in the nuts to meet the requirements when using the softer metals. Though the over-all height of the nut is less by the amount that the hexagon face is shortened, the tapping, being in brass, can be carried somewhat deeper than is practicable when tapping in steel. Finished appearance of the assembly in which this style of nut is used is the chief requirement, as the strength is necessarily limited by the material.

With regard to nomenclature, the Division feels that the term "acorn" is properly applicable to but one shape and that the term "blind" is appropriate from the manufacturing standpoint as referring to the tapped hole, which is not in evidence after the nut is assembled. The terms "crown" and "cap" are both correct as applying to the appearance of the nut. On account of its trade use in catalogs, the Division has proposed that the term "cap nuts" be adopted as the logical one.

The accompanying recommendation by the Division is published in this issue of the S.A.E. JOURNAL to give the entire industry an opportunity to review it and with the request that those who are interested indicate to the Standards Department of the Society whether the proposed standard will be acceptable if adopted by the Society. Comments should be returned as promptly as possible so that the Division can make a definite recommendation to the Standards Committee and the Society by the time of the Summer Meeting next June.





DIMENSIONS FOR PROPOSED STANDARD CAP NUTS

NUT SIZE *D*	No. 6	No. 8	No. 10	No. 12	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
C	3/16	3/16	15/64	15/64	1/4	17/64	19/64	11/32	3/8	7/16	7/16	17/32	39/64	11/16	25/32	27/32
F	5/16	5/16	3/8	3/8	7/16	1/2	9/16	5/8	3/4	7/8	15/16	1 1/16	1 1/4	1 7/16	1 5/8	1 13/16
R	9/64	9/64	11/64	11/64	3/16	13/64	15/64	9/32	5/16	3/8	3/8	7/16	33/64	19/32	43/64	47/64
S	3/64	3/64	3/64	3/64	3/64	3/64	3/64	3/64	3/64	1/16	1/16	5/64	3/32	3/32	1/8	1/8
L	1/32	3/64	3/64	3/64	3/64	3/64	5/64	3/32	7/64	1/8	1/8	5/32	3/16	7/32	1/4	1/4
B	3/32	3/32	9/64	1/8	1/8	1/8	1/8	9/64	5/32	3/16	11/64	13/64	7/43	1/4	9/32	5/16
T	5/32	5/32	3/16	7/32	1/4	5/16	3/8	7/16	1/2	9/16	5/8	3/4	7/8	1	1 1/8	1 1/4
P	21/64	11/32	27/64	7/16	15/32	17/32	5/8	23/32	13/16	15/16	63/64	1 3/16	1 3/8	1 9/16	1 25/32	1 15/16

A, for sizes No. 6 to 7/16 in. inclusive = hexagon size — 1/32 in.
for sizes 1/2 to 1 1/4 in. inclusive = hexagon size — 1/16 in.
F = Light (S.A.E.) hexagon sizes.
F^1 = Hexagon size for regular or heavy nuts.
H, for No. 6 to No. 10 inclusive = *D*.
for No. 12 to 1 1/4 in. inclusive = 7/8*D*.
H^1, for thin nuts, light (S.A.E.) hexagon sizes only = 3/4*D*.
R^1, for sizes No. 6 to 7/16 in. inclusive = hexagon size — 1/32 in.
for sizes 1/2 to 1 1/4 in. inclusive = hexagon size — 1/16 in.
The thread in the hole to be countersunk 35 deg. with the face of the nut and to the diameter of the tap.
Note.—For the short-type nuts, *T* must be reduced by the amount $H - H^1$.

News of the Sections

Met. Section Motorboat Meeting

History, Production, Harboring and Fire Protection Occupy Well-Attended Session

WHAT IS a marina? If you do not already know, you may still be one jump ahead of the dictionaries; you are two jumps ahead if you attended the Motorboat Meeting of the Metropolitan Section on Thursday evening, Feb. 18, at the A.W.A. Clubhouse in New York City. Richard R. Blythe introduced this name for a combination of waterside park and mooring harbor for motorboats, and told of a tour of the cities of the Country which he made to survey their harbors for motorboats.

Other leading speakers at the meeting, the arrangements for which were made by William Edgar John, New York City manager fo the Sterling Engine Co., were George W. Sutton, Jr., president of Sutton & Schipper; Kenneth M. Smith and Earl Hatton, of the Horace E. Dodge Boat Works, Inc.; and James Craig, a pioneer designer of motorboat engines. The attendance of 115 at the dinner was augmented by approximately 50 more who came to listen to the papers.

Chairman Jack Cramer first called upon F. K. Glynn, who told of his challenge to the Detroit Section in connection with the Get-Your-Man campaign. He also awarded the Section prize for the month, which was a tire and tube provided by the Firestone Tire & Rubber Co., to L. R. Joslin, of the Standard Oil Development Co., who had turned in two or three more membership applications than any other Section member since the campaign started. Monthly prizes of this sort will be a feature of Met. Section meetings for the remainder of the season.

History of Motorboating

Mr. John, who was then called to the chair, asked Mr. Sutton to read his paper on the History and Growth of Motorboating. This he traced from 1804, when Oliver Evans built a scow-like contraption equipped with four wheels. He drove this under its own steam power through the streets of Philadelphia, took off its wheels at the Delaware River and drove it, still under its own power, all the way to Delaware City. Other significant developments which he dated were the naphtha launches of 1884 and the first gasoline motorboat of about 1893. The first Gold-Cup Race developed the startling speed of 23½ m.p.h. in 1904. The present record is more than 110 m.p.h.

The year before this first race, Ole Evinrude got so tired of rowing across a Wisconsin lake on a hot summer day that he designed the first outboard engine, thereby initiating an industry that has developed wonderfully in the last few years. Racing speeds of these little craft have advanced from 16 m.p.h. in 1925 to nearly 57 m.p.h.

The American Power Boat Association, the ruling power in motorboat racing, Mr. Sutton regards as the greatest salesman in the industry; and the development of protected motorboat harbors which is now going on he characterized as "the good-roads movement for motorboats." The three roads to success, he said, are exploitation and merchandising, good roads and decent legislation.

The majority of our motorboats were said to be made by more than 3000 beach and band-saw builders, in spite of the existence of several quantity-production plants. The relative size of the industry is indicated by the findings of a survey made by the General Motors Corp. to the effect that all the engines which that company could hope to sell to the motorboat world in a year could be built in one day in one of the smallest factories of the company.

Mr. Sutton supplemented his paper with a score of slides showing characteristic and historic motorboats of the past and present, concluding with the proposed motorboat harbor alongside Riverside Drive in New York City.

Kenneth M. Smith followed with introductory remarks about the development of the Horace E. Dodge motorboat plant at Newport News, Va. The establishment of the plant was preceded by a thorough survey of manufacturing processes in a large number of woodworking and other industries, after which a most modern manufacturing method was planned and embodied in what is called the world's largest motorboat plant. The speaker passed over to Earl Hatton, production manager of the plant, the task of outlining the way in which line-production methods have been applied in this industry and the highly efficient mechanical aids that are provided. Mr. Hatton's talk was followed by motion pictures showing various operations in turning out the standardized runabouts that are produced by this company.

Marina Makes Her Bow

Mr. Blythe took up the subject that was introduced by Mr. Sutton's last picture when he ascended the rostrum to give a racy talk on the national marina survey, in part of which he was accompanied by Ira Hand, secretary of the National Association of Engine and Boat Manufacturers, an organization which sponsored the survey. Mr. Blythe's talk was illustrated by many "before and after" views of the waterfronts of various cities and was interspersed with so many comic remarks that his audience laughed more continuously than they would for any professional humorist. Nevertheless, he presented very strongly the remarkable development that is going on in the provision of marine parks and yacht basins in the many waterfront cities.

The marina is described as a combination of attractive waterfront park, having parking facilities for automobiles, with a motorboat basin having facilities for mooring boats at docks. A characteristic design that was shown provided floating piers in alternate spaces between boats, the bows of which are moored to the shore, while their sterns are moored to piles located at the ends of the docks and midway between docks.

Fire-Prevention Regulations

James Craig, who formerly was builder of the well-known Craig engines, gave the last paper of the meeting. This was on the subject of Fire Prevention Aboard Motorboats. Reference was made to the conclusions presented through the National Fire Prevention Association in Appendix D of the Regulations Governing Marine Fire Hazards. These regulations have been approved and recommended by the National Association of Engine and Boat Manufacturers, and copies can be obtained gratis.

Filling the gasoline tank is regarded as a critical period for safety. Concentration and care should attend this operation, and it is recommended that no unnecessary persons be allowed on board the craft during it. A filling station located on shore and provided with convenient servicing and emergency facilities is preferable. All ports, hatches and apertures should be closed to exclude the combustible gases.

Galley stoves are conceded to be the most backward detail on board a motorboat. Fuels of various sorts are used, some of them requiring preheating by means of a volatile liquid combustible and entailing a considerable amount of skill. Bottled gas is recommended as the most safe, simple and satisfactory fuel, but leakage of gas must be guarded against. Mr. Craig suggested that all fittings and connections be made of forged or rolled rather than cast material; the fittings should be specially made for the service and superior to the type used in automobiles. The suggestion was also made that cooking utensils should be ararranged with convenient devices whereby they can be affixed to and released from the gas range by a partial turn or some other convenient locking means, to prevent accidents in turbulent waters.

Walter C. Bauer, of the Standard

Oil Development Co., followed with a demonstration of a grade of hydrogenated gasoline which he considers ideal for motorboat use. He showed that it was impossible to ignite this gasoline with a match when a small quantity of it was dropped on an asbestos pad or poured into a small metal dish. The fuel has as octane rating of 95, and its only disadvantage is a difficulty in starting that is due to its narrow distillation range. More volatile fuel or electric heating devices are required for starting, and suggestions were invited.

George H. Townsend, president of the American Power Boat Association, and Ira Hand offered brief remarks in appreciation of the engineers and their Society, and the latter suggested the organization of a motorboat activity in connection with the Metropolitan Section. This suggestion was supported by Joseph Anglada, who said that anyone connected with the design, manufacture, selling or servicing of motorboats should be interested in such an activity.

Power-Control Session at Chicago

TRANSMISSION development and vacuum clutch control were the subjects of discussion that made the meeting of the Chicago Section on Feb. 2 at the Hotel Sherman one of the largest and best that have been held by the Section. Members and guests to the number of 140 enjoyed the dinner and entertainment, and 185 attended the technical session.

C. F. Rauen, chief engineer of the Detroit Gear & Machine Co., presented a paper on Automobile-Transmission Development, and a second paper, on Vacuum Clutch Control, by F. A. Bower, chief engineer, and John P. Heiss, development engineer, of the Buick Motor Co., was presented by Mr. Heiss, Mr. Bower being unable to be present.

The papers were discussed at length, those taking leading parts being F. H. Wells, of the Bragg-Kliesrath Corp., who submitted written discussion; D. G. Roos, of the Studebaker Corp.; Robert P. Breese, of the Bragg-Kliesrath Corp.; O. T. Kruesser, director of the Chicago Museum of Science and Industry; E. G. Hill, of the Hill Engineering Co.; and Lloyd Yost, of Fairbanks, Morse & Co.

Following the discussion, a two-reel motion picture illustrating a research study made in Germany of front-wheel tramp was shown through the courtesy of Dr. H. C. Dickinson, of the Bureau of Standards.

The primary advantage of the vacuum-operated clutch, according to Mr. Bower, is the reduction in manual effort required to release the clutch against the pressure of the stiff clutch spring; however, incidental advantages are that (*a*) the chronic clutch-pedal rider can ride the control button all the time without damaging the clutch; (*b*) the vacuum-operated clutch automatically cranks the engine if the engine stops when the car is coasting, provided a free-wheeling clutch is not used in combination with the clutch; (*c*) the car does not roll away when left at the curb with the engine dead and the gears in mesh; (*d*) should failure of the vacuum-controlled clutch occur, the car can be operated as a conventional car; and (*e*) locking out of the vacuum control, when desired, is accomplished quickly and easily without taking the driver's attention from the road.

The author reviewed the development of vacuum-operated clutches and described in detail the design and operation of the system developed by the Buick Motor Co.

Pittsburghers Discuss New Car Features

THE PRESENCE of A. J. Scaife, President of the Society, was a welcome surprise to the 45 members and guests who braved inclement weather to attend the dinner at the Feb. 2 meeting of the Pittsburgh Section and the 10 more who arrived later.

After a few remarks by President Scaife, Chairman B. F. Eaton presented General Manager Warner, who gave a brief outline of the Get-Your-Man campaign and its relation to the Pittsburgh Section.

J. W. Rickey, chief hydraulic engineer of the Aluminum Co. of America, then announced the recent discovery of the use of aluminum foil as a heat insulator, and said that 4 oz. of aluminum foil will insulate as effectively as 10 lb. of cork or 17 lb. of magnesia. He then showed slides and a motion picture entitled, Tipping the Chute-a-Caron Obelisk, which showed the accurate tipping into place by the use of dynamite of the obelisk weighing 11,500 tons, built to dam the river.

Harold F. Blanchard, technical editor of *Motor*, then presented a paper on The Engineering Features of New Cars. He said in part that car manufacturers have become astonishingly open-minded during the last few months, and, instead of waiting until there was a consumer demand for new features, they now feel that the more sales appeal they put into their new cars, the more cars they will sell in 1932. We now have a complete landslide to free-wheeling or to its lusty competitor, the vacuum-operated clutch. Virtually all cars have silent second-speed transmissions and synchronous meshing of second and high gears. Nearly all have larger-section tires on smaller-diameter rims of the drop-center type. The majority have wire wheels as standard.

Continuing, he said that most of us will agree that, either on a basis of novelty or merit, the automatic vacuum-operated clutch is the most important trend of the year. Another interesting development is the frames, and this is linked with the subject of engine mountings, which usually are of rubber, and the radiators, fenders, head-lamps and bodies.

The frame side members were likened to springs supporting various pendulums, including the powerplant, the radiator, the head-lamps and front fenders. These springy frame members are carried by the leaf springs, and, between them and the elastic tires, are the masses of the axles and wheels. Hitherto, when the pendulum mass of the powerplant was securely attached to the frame, it acted as a steadying factor against torsional vibration and the engine arms braced the frame; but, now that the engine is rubber mounted, the side frames tend to vibrate at their own natural rate, hence it is necessary to use stiffer frames or to brace them in some other way.

A number of members participated in a spirited discussion, including D. R. Harper, of the Carnegie Institute of Technology; President Scaife; A. R. Platt, of the Front-End-Alignment subcommittee; Section Chairman Eaton, of the Bell Telephone Co.; John A. C. Warner, general manager of the Society, Charles R. Noll, of the Gulf Refining Co.; and J. W. Rickey, of the Aluminum Co. of America.

Alloy Steels and Their Treatment

TWO PAPERS on alloy steels and their heat-treatment were presented and discussed at the Feb. 5 meeting of the Southern California Section, held at the Elks Club in Los Angeles. Fifty-four members and guests were present at the dinner and entertainment, and a dozen more came in later to hear the speakers.

The first paper, on Alloy-Mill Practice, was presented by George C. Stetter, metallurgist of the Pacific Coast Steel Corp.; and the second, on Heat-Treatment of Alloy Steels, was given by Richard S. Smith, metallurgist of the General Metals Corp.

Among those who discussed the subjects were James H. Spade, Fred C. Patton, Wendell E. Mason and Thomas S. Hutton.

A Nominating Committee to prepare a slate of candidates for Section offices for next year was appointed by Chairman W. E. Mason, and Col. W. H. Fairbanks spoke briefly on the Get-Your-Man membership drive.

The annual social party of the Section was set for April 9.

Philadelphians Told of Trends

MOTOR-CAR design trends of 1932 were pointed out and commented upon by Harold F. Blanchard, technical editor of *Motor*, at the monthly meeting of the Philadelphia Section on Feb. 10, which was held as usual at the rooms of the Philadelphia Automobile Trades Association. The technical session was preceded by the regular members' dinner accompanied by an entertainment under the direction of O. M. Thornton. In his address, Mr. Blanchard discussed recent improvements in engines and their mounting, cooling, tuned mufflers, automatic clutches, transmissions, two-ratio axles, frames, springing, adjustable shock-absorbers, and body streamlining.

Progress of the Year Reviewed at Baltimore

BALTIMORE Section members and guests to the number of 125 met in the ballroom of the Emerson Hotel in that city Thursday evening, Feb. 11, to hear Austin M. Wolf continue the story of Automobile Engineering Progress for 1932, which was begun in the S.A.E. JOURNAL for January, p. 25. Mr. Wolf described the progress on the 1932 models concerning which data were not available when the earlier paper was written.

Apropos of the 12-cylinder engines offered by Auburn and Packard, Mr. Wolf said that there is no doubt that all the cylinders of future V-type engines will be cast in one block with the crankcase, a practice which was introduced in the Viking eight. Valves in the Auburn-Lycoming engine are horizontal. The single camshaft is located below a hollow rocker-arm shaft, making the adjustment very accessible. The spark-plugs are placed in removable water-jacketed covers over openings through which the valves can be removed without disturbing the cylinder head. Cylinder heads also can be removed without disturbing the camshaft or the rocker-arms. The output of 165 hp. at 3500 r.p.m. is 1 hp. for each 2.38 cu. in. of piston displacement.

Valves of the Packard 12 are set at an angle and are actuated from a single camshaft and rocker-arms mounted with needle bearings on two rocker-arm shafts. Valve adjustment is by an automatic hydraulic adjusting mechanism. The cylinders of the Franklin 12 are set at 60 deg. Piston-pins in the Franklin are of nitrided steel.

Changes incident to automatic clutch control on the Packard, Cadillac, Chrysler and Dodge cars were described. Driving plates on the Cadillac clutches are made heavier and from molybdenum cast iron, which is said to be virtually proof against scoring. The control valve consists of three plungers, one of which is controlled by a button and the other two by connection with the accelerator pedal. The combination of free-wheeling and automatic clutch control takes the place of gear-speed synchronizers.

All gears in the Cadillac and Packard transmissions excepting the reverse gears are of the constant-mesh type with ground and lapped helical teeth. The helix angle in the Cadillac is 45 deg., and the shafts are mounted on tapered roller bearings. Ball bearings are used in the Packard transmission. The four-speed internal-gear transmission is found this year only in Chrysler eights.

Vacuum-Operated Dual-Ratio Axle

Mr. Wolf described as outstanding in rear-axle development the Auburn planetary-geared dual-ratio axle. Shifting from one ratio to another is accomplished through a double-acting piston actuated by inlet-manifold vacuum. A shut-off valve interconnected with the free-wheeling control prevents making this shift when the free-wheeling mechanism is locked out. Another interconnection is to the double-ratio speedometer head, so that this is shifted to correspond with the rear-axle ratio.

Suspension problems were said to have received much study in connection with the ride regulator on the Cadillac. The distance between the axle centers and the center of gravity of the car was determined experimentally with a view to better riding qualities, and reduction of unsprung weight was achieved which amounts to about 40 lb. at the front and 100 lb. at the rear.

Developments in body construction include spraying the inside of the panels with various compounds of asphaltum and provision of felt or fiber insulation at various points. Metal brackets have replaced glued joints in much of the Cadillac framework, the wooden parts being held out of contact with one another.

Mr. Wolf's conclusion was that the value per dollar given by the automobile industry this year is greater than in any previous year and greater than any other industry offers. Never has there been such an outpouring of new ideas, developments and results in performance. Having accomplished this, the automobile industry is bound to lead the Country back to better times.

Fire-Apparatus Engine Described at Syracuse

MEMBERS of the Syracuse Section, gathered at the monthly meeting on Feb. 9 at the Hotel Syracuse, heard Hubert Walker, chief engineer of the American-LaFrance & Foamite Corp., give under the title, Safeguarding America by Modern Methods, the paper he presented at the Annual Meeting of the Society. This was accompanied by lantern slides and motion pictures and described the design of the corporation's new V-12 250-hp. engine for use in fire-engines and motorcoaches. The reasons for the development of so powerful an engine and for various design features were given, as were also curves of horsepower, torque, brake mean effective pressure and specific fuel consumption.

Walker Gives Paper at Buffalo

UNDER the title The Latest Recruit in the Army of Protection, Hubert Walker presented at the Buffalo Section meeting on Feb. 16 the paper he gave at the Annual Meeting of the Society. In this was described the development of the V-12 250-hp. engine built for fire apparatus by the American-La France & Foamite Corp., of which Mr. Walker is chief engineer. Motion pictures of tests of the new engine and of fire fighting were shown to supplement the paper.

The meeting was attended by 76 members and guests, and among those who took an active part in the discussion were Fire Chief Hedden, Harry Achurch, H. J. Helfrich and H. E. England.

New Englanders Consider Car Electrical Equipment

STARTING, lighting and ignition units were explained and discussed at a gathering of about 100 members and guests of the New England Section at the Walker Memorial Building in Cambridge, Mass., on Feb. 10, and so many questions were asked of the speakers that the meeting did not adjourn until 11:30 p. m.

J. L. Arthur, of the Delco-Remy Corp., gave an excellent short paper in which he described and explained many things about electric starters, lighting generators, the voltage and current regulator, the cut-out relay, the ignition distributor, the ignition coil and the battery. In conclusion, he said that the present trend is toward more accessories on automobiles, mostly electrically operated; that cars are being driven faster and require larger-candle-power head-lamps and multiple beam; that water heaters, cigar lighters and the like add to the demand upon the generator without provision being made for the larger generator needed, and that therefore it is self-evident that an automobile that performs satisfactorily is one on which the electrical requirements have received very careful consideration.

Sumner S. Howard, of the A. C. Spark Plug Co., gave an instructive talk on spark-plugs and a complete tune-up of cars. For full measure, he also discussed fuel-pumps.

Talks on the S.A.E. Get-Your-Man Campaign were made by Past-Chairman Albert Lodge and A. J. Underwood, of the Society's staff.

Looking for Trouble in Aircraft Engines

R. M. HAZEN, assistant engineer of the American Airplane & Engine Corp., of Farmingdale, L. I., N. Y., presented a paper bearing the title, Looking for Trouble in Aircraft Engines at the Jan. 29 meeting of the Wichita Section. The meeting, which was held at the Green Parrot Inn, was attended by 22 members and guests, following a member's dinner.

The specific troubles dealt with by Mr. Hazen were those encountered in the development by his company of six and twelve-cylinder in-line inverted air-cooled aircraft engines. They were associated with increase in revolutions per minute and in brake mean effective pressure without corresponding increase in weight or decrease in strength. Some of the problems related to reduction-gear propeller drive, direct fuel injection, supercharging, torsional oscillation of the camshaft, cooling of the exhaust valves, oil leaks and local hot spots.

Numerous questions about the new engine were asked in the discussion and answered by Mr. Hazen.

Among those who took part in discussion of the subject were R. R. Higginbotham, Mac Short, H. F. Brown, F. Landgraf, Eldon Cessna, Harold Wzipp and E. T. Allen.

Milwaukee Section's Varied Program

IMPRESSIONS of Soviet Russia's present industrial status, enlivened by motion pictures; the inspection of metal parts by means of X-rays; motion pictures furnished by the Waukesha Motor Co. illustrating the characteristics of an oil film within a glass bearing under variable speed and load conditions; and an outline of the present state of delevopment of the plans for the World's Fair to be held at Chicago in 1933, were the subjects presented at the Milwaukee Section meeting held at the Milwaukee Athletic Club on Feb 3. A dinner was served to 75 members and guests; 142 attended the technical session. Henry L. Debbink was chairman.

L. J. Kanitz, general sales manager for the Continental Motors Corp., describe his recent trip to Russia and outlined his impressions from an automotive-engineer's viewpoint. The motion pictures which illustrated current conditions in Russia were made available by the courtesy of A. R. Smith, manager of the industrial division of the corporation. According to Mr. Kanitz, the five-year plan continues to be Russia's inspiration and guiding star; but, to him, the accomplishment of this plan within the scheduled limit is doubtful.

X-Rays for Automotive-Industry Use

A. W. Page, industrial engineer of the General Electric X-Ray Corp., introduced the audience to the methods of using X-rays for the inspection of castings, valves and welded joints, as shown by lantern slides. In addition, applications of the X-ray in the medical field and in the United States Mail Service were discussed.

According to Mr. Page, the "inside story" of metals is made available to the foundry by the X-ray, it being of great assistance in detecting blowholes and thus affording an opportunity for eliminating them, in the detection of excessive localized shrinkage and in reducing waste in the form of scrap material. Other uses relate to the exact location of chills, the attainment of correct pouring temperatures and the like. Suitable methods of X-ray use also were featured.

Hear History of Niagara

AT THE meeting of the Canadian Section at the Royal York Hotel in Toronto on Feb. 17. Jack Stewart, manager of the Canadian Automobile Chamber of Commerce, stated that a National Motor Show will be held in Toronto from March 5 to 12, and that on March 8 the Canadian Section and the Automobile Chamber will have a joint dinner at the Royal York, at which the Hon. H. H. Stevens, Minister of Trade and Commerce for Canada, probably will be present. Sir Malcolm Campbell may also attend and Section Secretary W. B. Hastings said he had received an intimation that Sir Dennistoun Burney would be present with his streamlined car.

Alex S. McArthur presided in the absence of Chairman G. W. Garner, and there were about 50 members on hand.

Vice-Chairman A. N. Bentley, general manager of Exide Batteries, Ltd., of Canada, the speaker of the evening, spoke on the History of Niagara and the changes that have occurred there during the successive geological ages. He showed that at one time the entire district was under salt water, as evidenced by the marine deposits.

Dealing with the gradual recession of the falls, Mr. Bentley said that the water flowed over hard limestone rock, but that the soft shale below was worn away by the spray, with the result that the limestone kept breaking off. At present 50,000 cu. ft. of water per sec., or about one-quarter of the entire flow, is being diverted for power purposes. It has been demonstrated, however, that as much more could be used for power, without destroying the beauty of the falls, by the construction of islands above them which would spread the water more evenly.

Gordon Monahan helped to round out the evening's entertainment with a sound picture dealing with the making and uses of Raybestos.

Indiana Section's New-Car Meeting

A CAPACITY crowd of 225 members and guests, many of whom came long distances, made the Review-of-the-Shows meeting of the Indiana Section on Feb. 11 quite out of the ordinary. The members' dinner preceding the technical session was attended by 67. After electing a Nominating Committee for the nomination of Section officers for the next Section year, the assemblage heard Herbert C. Snow, vice-president of the Auburn Automobile Co., give a good technical review of the new features of cars displayed at the winter's automobile shows and roared with laughter as Lee Oldfield jested in a good-natured vein at some of the new designs and some new gadgets that "do perfectly beautiful things uselessly." Both talks were illustrated with slides. Mr. Snow's discourse was very complete and satisfying to the listeners, who gave close attention for an hour to the most thoughtful show review they had ever heard.

The Chairman announced that the March 10 meeting will be devoted to the subject of engines, on which two speakers will be heard, and that in April it is planned to hold two sessions at Purdue University on research, with a dinner between the afternoon and evening sessions.

A special plea to Section members for energetic action in the Society's membership drive was made.

Talking Pictures Evoke Discussion

MUCH discussion of a technical nature followed the showing of a four-reel talking picture describing the manufacture and testing of the engine suspension of the Plymouth car by W. H. DeLancey, of the Chrysler Corp., at the meeting of the Kansas City Section on Feb. 18 at the Savoy Hotel. Twenty-four members were in attendance following the customary dinner. A complete engine was displayed and was inspected with a great deal of interest, many questions being asked of Mr. DeLancey.

Brakes and Lining Hold Clevelanders' Interest

CLEVELAND Section's February meeting on the 15th at the Cleveland Club, following a members' dinner and entertainment, was devoted to the subject of brakes and brake lining. The only paper given at the meeting was on Power Brakes for Passenger-Cars and was presented by Howard K. Gandelot, experimental engineer of the Stewart-Warner Corp. The other feature of the evening's meeting was the showing of a talking picture entitled, The Manufacture of Brake Lining, showing the process employed by the World Bestos Corp.

In his paper, Mr. Gandelot mentioned the heavy responsibility that is being thrown upon the brakes by the higher speed of which cars are capable and by the adoption of free-wheeling devices. He also pointed out that cars are increasingly being driven by women and hence quick, safe and accurate stopping with the minimum of muscular effort is essential. Therefore the need for power braking has been definitely established.

The speaker classified power brakes as electric, air, oil or hydraulic, vacuum and mechanical, and described each type briefly. The latter part of the paper was devoted to a detailed description of the construction and action of the direct-acting mechanical power brakes produced by the corporation with which Mr. Gandelot is connected. This, he said, requires only light foot pressure applied to a short-range treadle-type pedal. The force exerted is amplified mechanically and distributed by simple, rigid linkage in exactly equal predetermined amounts to the two front wheels and in similarly predetermined equal amounts to the rear wheels. The amplifying mechanism is built integrally with or attached to the transmission case.

With the continued development of transmissions, which may eventually result in total elimination of the clutch pedal, Mr. Gandelot foresees the possibility that cars in the future may be entirely controlled by two short-range pedals; one, the accelerator and the other, the brake pedal.

Cut-away models of various parts of the power-brake mechanism and a power unit mounted on a transmission were displayed. Although the meeting did not adjourn until 11 p. m., many members remained for half an hour to inspect the models. Leading parts in the discussion of the paper were taken by H. E. Simi, of the Twin Coach Co.; Stanley Johnson, of the Bendix-Westinghouse Brake Co.; and William Piwonka, of the Cleveland Railway Co.

Personal Notes of the Members

Schildhauer Joins General Aviation

Having severed his connection with the Dornier Co. of America, Clarence H. Schildhauer assumed new duties on Jan. 1 with the General Aviation Mfg. Corp., of Dundalk, Md., which is engaged in the manufacture of commercial and military airplanes and flying-boats. He is engaged in development and sales work.

Mr. Schildhauer, who became a member of the Society in May, 1930, is a native of Wisconsin and a graduate in 1918 of the United States Naval Academy. He was commissioned a lieutenant and served on destroyers in European waters during the World War and entered military aviation in 1921. He formed aircraft squadrons with the scouting fleet in 1923, made the flight from Hampton Roads, Va., to Panama in the F-5-L and operated it along the Atlantic Coast, became test pilot at the Naval Aircraft Factory at Philadelphia in 1925, held the world seaplane endurance record from 1925 to 1928, and was alternate pilot on the Navy flight from California to Hawaii in 1925. During the next four years he organized and commanded the Aerial Survey Unit in Cuba, made a non-stop flight in the PN-9 from Hampton Roads to Panama, was in charge of the experimental squadron at Hampton Roads where he worked on the improvement and development of avigation instruments and seaworthiness characteristics of flying-boats, made aerial surveys of Cuban and Mexican Gulf ports, and organized the Scouting Fleet flying-boat squadron. At present he holds the rank of lieutenant-commander, United States Naval Reserve, for general aviation duties.

Mr. Schildhauer joined the Dornier company in 1929 and last year made the flight in the Do-X from Europe to South America and north to New York City. He presented at the Metropolitan Aeronautic Meeting of the Society in May, 1930, a paper by Dr. Claude Dornier giving a technical description of this ship. The paper was published in the S.A.E. JOURNAL for May, 1930, p. 554.

Elected to Office in Motorcycle Association

At the annual meeting of the Motorcycle and Allied Trades Association, held in New York City recently, a number of members of the S.A.E. were elected to office. Arthur Davidson, sales manager of the Harley-Davidson Motor Co., was elected treasurer and the following men were elected to serve this year on the board of directors: E. Paul duPont, president of the Indian Motorcycle Co.; F. J. Weschler, vice-president and treasurer of the Baldwin-Duckworth Chain Corp.; and E. L. Stoughton, vice-president of the Wico Battery Co.

The association voted to increase its activities throughout the Country to induce a more general participation by the public in use of the motorcycle; to start a movement to secure greater recognition of the motorcycle as a part of the automotive industry; and to initiate a campaign to inform the public regarding the safety of the motorcycle and to urge users not to indulge in riding practices that create the impression of danger.

Tipper Leaves General Motors

Harry Tipper resigned recently as vice-president and general sales manager of the General Motors Export Co., in New York City, to go into consulting work on distribution, merchandising and advertising. This is a line of work with which he has been intimately associated, having founded and served as the first president of the Advertising Club of New York, president of the Associated National Advertisers, president of the Technical Publicity Association and former chairman of the educational committee of the Associated Advertising Clubs of the World. Together with Professor Hotchkiss, he organized the New York University School of Marketing and also served as a member of the University faculty.

Mr. Tipper was born at Kendal, England, and acquired his technical training in the Kendal Science School and in the Technical School of Glasgow, Scotland. After devoting his early business activities to engineering work in several British industries, he came to this Country in 1903 to work on the construction of the first Hudson River tunnel. Subsequently he served successively the Interborough Rapid Transit Co. and the Electric Lighting Commission in New York City; the Ingersoll-Rand Co. as sales engineer, the Texas Co. as sales engineer and advertising manager, and *Automotive Industries* as manager. He became general sales manager of the General Motors Export Division in 1925.

Mr. Tipper was elected to Member grade in the Society in March, 1912.

Chamberlin Flies High

An official altitude record of 19,363 ft. for Diesel-powered airplanes was established on Jan. 24 by Clarence D. Chamberlin at Floyd Bennett Field, the New York City municipal airport in Brooklyn. He used the Lockheed Vega plane driven by a 225-hp. Packard Diesel engine in which he just previously had flown from Detroit to Brooklyn at a cost for fuel of only $4.

The altitude flight was made in 1 hr. 5 min., and a temperature of 17 deg. fahr. below zero was encountered at the peak of the climb. The barograph showed a constant rate-of-climb curve that was one long oblique line, in contrast with the curve recorded with supercharged engines, which slopes sharply upward in the first stages, then flattens off as the ceiling is reached and the gasoline engine begins to lose power in the rarefied air. When the Diesel-engined plane reached the level at which Mr. Chamberlin needed to resort to the oxygen supply to aid his breathing, the throttle of the engine had to be partly closed to maintain maximum engine speed, as the throttle regulates only the quantity of fuel injected, which, for best combustion, should be reduced in the lighter air.

Heraclio Alfaro has been named as vice-president and chief engineer of a new company organized under the title of F. W. Steere Co., for the manufacture of Autogiros under license from the Autogiro Co. of America. Mr. Alfaro, who secured his pilot's license in France in 1911 and built several of the early airplanes of Spanish manufacture, has been actively associated with Autogiro work in America for the last 2½ years.

Edward M. Bertran has been made chief engineer of the aircraft division of Charles M. Stieff, Inc., of Baltimore, which is engaged in the manufacture of aircraft parts. He formerly filled a similar position with the aircraft division of Brewster & Co., Inc., of Long Island City, N. Y.

Joseph M. Buswell is now engaged in research work at the Bureau of Standards in the City of Washington as junior aeronautic engineer. His previous connection was with the Curtiss Aeroplane & Motor Co., of Buffalo.

Juan de la Cierva, inventor of the Autogiro, sailed for England in February after a six-weeks' visit to this Country, during which he was engaged in a series of experiments with the engineers of the Autogiro Co. of America at the company's flight-research field at Willow Grove, Pa., for the further development of the flight principle of the machine. While in America Mr. Cierva was successively entertained by President Hoover, Henry Ford and other National personages.

Arthur E. Corbin recently became associated, as special representative, with the S. E. Sales Co., of Atlanta, Ga., a unit of the General Motors Corp. Before accepting this position, he was zone sales manager for the Oakland Motor Car Co., in New York City.

Duncan P. Forbes has been elected president and general manager of the Gunite Foundries Corp., of Rockford, Ill. The corporation was formed recently by the consolidation of the Rockford Northwestern Malleable Corp. and the Gunite Corp., of both of which Mr. Forbes was president.

F. M. Germane, having relinquished his position of special sales representative for the Budd Wheel Co., of Detroit, is now acting as manufacturers' agent in Detroit.

Bennett Hill, who was chief engineer of the Dee Wite Boat Co., of River Rouge, Mich., has entered the employment of the H. E. Dodge Boat & Plane Co., of Newport News, Va., in the same capacity.

(*Concluded on p.* 52)

Applicants Qualified

The following applicants have qualified for admission to the Society between Jan. 10 and Feb. 10, 1932. The various grades of membership are indicated by (M) Member; (A) Associate Member; (J) Junior; (Aff.) Affiliate; (S M) Service Member; (F M) Foreign Member.

ANTHONY, RICHARD L. (M) instructor, mechanical engineering, Yale University, New Haven, Conn.; (mail) 135 Filbert Street, *Hamden, Conn.*

BAUER, M. H. (F M) director, Fertigung G.m.b.H., Potsdamerstrasse 28, *Berlin W. 35, Germany.*

BERGSTROM, S. E. (M) sales manager, branch office, Cincinnati Milling Machine Co., Cincinnati Grinders, Inc., 401 New Center Building, *Detroit.*

BIRREN, WILLIAM B. (M) western service representative, Wright Aeronautical Corp., Paterson, N. J. (mail) 1149½ Wooster Street, *Los Angeles.*

BOCK, GEORGE E. (M) 304 West 107th Street, *New York City.*

BRUCE, ERNEST G. (J) General Aviation Mfg. Co., *Dundalk, Md.;* (mail) 8 Arrowship Road.

BURRISS, LUTHER J. (J) mechanical engineer, South Carolina State Highway Department, *College Place, S. C.;* (mail) Box 101.

CAVIN, GUSTAVE (M) chief mechanical engineer, Canadian Locomotive Co., Ltd., *Kingston, Ont., Canada.*

CUMMINGS, EVERETT D. (A) branch manager, International Harvester Co. of America, 920 East 25th Street, *Baltimore.*

DAVIES, J. H. (J) mechanical superintendent, B. C. Motor Transportation, *Vancouver, B. C., Canada;* (mail) 2221 Brunswick Street.

DOWD, RAYMOND E. (M) aeronautical engineer, automotive representative, Russell Mfg. Co., 1901 Indiana Avenue, *Chicago.*

DRAKE, JOSEPH S. (M) motor-vehicle supervisor, Sinclair Refining Co., New York City; (mail) 5847 Saul Street, *Philadelphia.*

DRYSDALE, GEORGE W. (A) superintendent, commercial division, Briggs Mfg. Co., *Detroit;* (mail) 5301 Bedford.

EVANS, F. B. (A) partner, Paul H. Davis & Co., 37 South LaSalle Street, *Chicago.*

GUIMOND, GEORGE L. (A) Canadian sales agent, Bridgeport Fabrics of Canada, Ltd., St. Hyacinthe, Que., Canada; (mail) 11-254 General Motors Building, *Detroit.*

HABACH, GEORGE F. (J) computer, Worthington Pump & Machinery Corp., Harrison, N. J.; (mail) 714 Valley Street, *Orange, N. J.*

HERVEY, JOHN P. (J) research student, Harvard University, Cruft Laboratory, *Cambridge, Mass.*

HILL, JAMES R., MAJOR (S M) United States Army, Quartermaster Corps, Army War College, *City of Washington.*

KOHLER, HENRY L., JR. (J) instructor, mechanical engineering, University of Michigan, 209 West Engineering Annex, *Ann Arbor, Mich.*

KRAMER, FRED S. (J) 26 West 96th Street, *New York City.*

LELAND, WILLARD E. (A) National user salesman, International Harvester Co. of America, *Baltimore;* (mail) 4401 Ethland Avenue.

LUCAS, JOSEPH E. (A) president, Diesel Oil Sales Co., 115 Belmont Avenue, North, *Seattle, Wash.*

MAVERICK, GEORGE M. (M) director, research laboratories, Standard Oil Development Co., Linden, N. J.; (mail) P. O. Box 485, *Elizabeth, N. J.*

MILLER, GEORGE HERBERT (A) sales representative, Collins & Aikman, Farnham, Que., Canada; (mail) 175 Madison Avenue, *Toronto, Ont., Canada.*

MORTON, JAMES (A) foreign representative, Willard Storage Battery Co., *Johannesburg, South Africa.*

PADDOCK, PAUL DARROW (A) counsellor in public relations, Hayes, Loeb & Co., *Chicago;* (mail) 1100 North Dearborn Parkway.

PAIGE, EDWIN C. (J) sales engineer, Ethyl Gasoline Corp., 1004 Court Square Building, *Baltimore.*

PANGBORN, EDWARD L. (M) chief draftsman, in charge of body detailers, Ford Motor Co., Dearborn, Mich; (mail) 4516 Allendale Avenue, *Detroit.*

PARTENHEIMER, JOSEPH E. (M) manager, product development, Fisk Rubber Co., 154 Grove Street, *Chicopee Falls, Mass.*

PATCHETT, ULYSSES A. (M) instructor, mechanical engineering, Stanford University, Calif.; (mail) 1854 Bryant Street, *Palo Alto, Calif.*

ROBERTSON, DELMAR D. (J) engineer, Wilkening Mfg. Co., 71st and Church Lane, *Philadelphia.*

ROBISON, J. ARLEY (M) automotive district representative, Hendler Creamery Co., Inc., 1100 East Baltimore Street, *Baltimore.*

SHANK, LOUIS WARREN (A) sales engineer, Ethyl Gasoline Corp., *Baltimore;* (mail) 104 Mallow Hill Road.

SPERLING, MILTON (J) automotive engineer, southern division, Richfield Oil Co., Los Angeles; (mail) 1146 Diamond Avenue, *South Pasadena, Calif.*

STROMQVIST, VIDMAR BIRGER (J) engineer, Chrysler Corp., *Detroit;* (mail) Y.M.C.A., 13220 Woodward Avenue.

SUNNEN, JOSEPH (A) president, Sunnen Products Co., 7900 Manchester, *St. Louis.*

WEST, HARRY T., JR. (A) sub-foreman, Boeing Airplane Co., *Seattle, Wash.;* (mail) 712 31st Street, South.

WINDLE, WILLIAM JOHN, JR. (J) vice-president, W. & B. Auto Radiator & Repair Co., 33 Washington Avenue, *Irvington, N. J.*

ZIMMERMAN, H. W. (M) engineer, Automotive Maintenance Machinery Co., *Chicago;* (mail) 4121 West Adams Street.

Applicants for Membership

The applications for membership received between Jan. 15 and Feb. 15, 1932, are listed below. The members of the Society are urged to send any pertinent information with regard to those listed which the Council should have for consideration prior to their election. It is requested that such communications from members be sent promptly.

ANGSTMAN, ROGER W., president, Roger Angstman Co., *Detroit.*

BEAM, HARRY A., designer, Consolidated Aircraft Corp., *Buffalo.*

BISTROM, F. VERNON, engineer, Isaacson Iron Works, *Seattle, Wash.*

BOUDREAU, JAMES E., division manager, Ethyl Gasoline Corp., *New York City.*

BRETTELL, CLINTON, superintendent of garages, R. H. Macy & Co., Inc., *New York City.*

BURDEN, PHILIP BYRON, mechanical draftsman, Municipal Tramways Trust, *Adelaide, South Australia.*

BURNEY, SIR CHARLES DENNISTOUN, chairman, Streamline Cars, Ltd., *London, England.*

COPE, RALPH LELAND, automotive research engineer, Vacuum Oil Co., Inc., *Paulsboro, N. J.*

CURTIS, GEORGE W., district manager, Timken Roller Bearing Co., *Milwaukee.*

DAY, RAY E., president, Ray Day Piston Corp., *Detroit.*

EPPLEY, EVERETT L., mechanical superintendent, Bates Motor Transport, *Chicago.*

FARMER, ROBERT, sales manager, Cities Service Oil Co., Ltd., *Toronto, Ont., Canada.*

FREI, J. RUDOLF, chief draftsman, Scintilla Magneto Co., *Sidney, N. Y.*

GOLBER, MYRON B., industrial engineer, Armour & Co., *Chicago.*

HAASE, HENRY MILTON, senior, University of Wisconsin, *Madison, Wis.*

HALEY, MERRITT W., service engineer, Pierce-Arrow Motor Co., *Buffalo.*

HARKRADER, WALLACE M., assistant sales manager, Perfect Circle Co., *Hagerstown, Ind.*

HARRINGTON, JOHN HOWARD, gas-appliance sales, Dayton Power & Light Co., *Dayton, Ohio.*

HAWLEY, CHARLES D., assistant director, engineering laboratory, Ethyl Gasoline Corp., *Detroit.*

HEADDEN, WILLIAM P., mechanical engineer, Standard Oil Development Co., *Elizabeth, N. J.*

HEISS, JOHN PAUL, development engineer, Buick Motor Co., *Flint, Mich.*

HOPKIN, WILLIAM B., automotive mechanic, Edmonton Motors, Ltd. *Edmonton, Alta., Canada.*

HUNT, CHARLES H., student, Swarthmore College, *Swarthmore, Pa.*

KEELING, HAL R., vice-president, Sidner, Van Riper & Keeling, Inc., *Indianapolis.*

KNOPE, PHILLIP F., draftsman, 6625 Mack Avenue, *Detroit.*

KURT, O. EDWARD, tire engineer, United States Rubber Co., *Detroit.*

LATIMER, GEORGE T., manager, industrial division, S. S. White Dental Mfg. Co., *New York City.*

MARCHAND, WILLIAM CHARLES, layout and design, Continental Motors Corp., *Detroit.*

MARSHALL, HARRY LYON, salesman, Sunset Pacific Oil Co., *Los Angeles.*

MILLER, RAY E., inspector of tanks, Ordnance Department, United States Army, *Fort George G. Meade, Md.*

MORIARTY, J. B., manager automotive sales, Canadian Industries, Ltd., *Toronto, Ont., Canada.*

MUSSELWHITE, HENRY E., president, manager, Musselwhite Machine Co., *Portland, Ore.*

NAVARO, ALFRED RALPH, automotive electrical instructor, Automotive Trades School, *Cincinnati.*

O'NEAL, ROBERT PAUL, foreman engine overhaul, American Airways, Inc., *Robertson, Mo.*

OSZMAN, HAROLD EDWARD, superintendent of transportation, Northern States Power Co., *Minneapolis.*

PECK, DONALD E., engine designer, H. E. Dodge Boat & Plane Corp., *Newport News, Va.*

PELTON, C. C., service superintendent, McCoy Auto Co., *Vancouver, Wash.*

PITTS, T. G., president, Aircraft Sheet Metal Co., *Wichita, Kan.*

PROSSER, WILLIAM B., branch factory manager, Perfect Circle Co., *Tipton, Ind.*

RABEIRIN, JEAN, engineer, Automobiles Renault, *Courtevoie, Seine, France.*

RAMMING, WILLIAM A., JR., general engineering, Busch-Sulzer Bros., Diesel Engine Co., *St. Louis.*

RECTOR, CLINTON, engineer, Bakelite Corp., *New York City.*

RITZ, FREDERICK, superintendent, precision pump department, Fairbanks, Morse & Co., *Beloit, Wis.*

ROSS, SIMON M., junior mechanical engineer, Aeronautical Engine Laboratory, Navy Yard, *Philadelphia.*

RUPERTUS, JOHN F., supervisor of motor equipment, Chesapeake & Potomac Telephone Co., *Baltimore.*

SCHWARZ, S. C., chief chemist, Portland Gas & Coke Co., *Portland, Ore.*

SHIPLEY, JEROME WILSON, installation department, Pratt & Whitney Aircraft Co., *East Hartford, Conn.*

STANLEY, RICHARD O., district master mechanic, Department of Highways, State of Washington, *Vancouver, Wash.*

STEWART, JOHN LESLIE, general manager, Canadian Automobile Chamber of Commerce, *Toronto, Ont., Canada.*

TAYLOR, CLINT L., first lieutenant, United States Army, Field Artillery School, *Fort Sill, Okla.*

TAYLOR, OTIS A., research test engineer, Continental Motors Corp., *Detroit.*

TIRRELL, EDWARD, automotive engineer, Utilities Management Corp., *New York City.*

WEBSTER, WALTER W., head, airplane design, Bureau of Aeronautics, United States Navy, *City of Washington.*

WICKS, EDGAR J., proprietor, Autocraft Organization, *New York City.*

WIGGIN, G. O., draftsman, American Airplane & Engine Corp., *Farmingdale, N. Y.*

WYLLNER, HERBERT P. H., instructor in automobile mechanics, Philadelphia Public School System, *Philadelphia.*

Frederic W. Warner

AFTER a brief illness, Frederic W. Warner, retired from the automobile business, died at his home on Dunedin Island, near Clearwater, Fla., on Feb. 14. He had for a number of years been president and general manager of the Oakland Motor Car Co., of Pontiac, Mich., and a member of the board of directors of the General Motors Corp.

Mr. Warner was born at Beloit, Wis., in 1866, and as a young man was engaged for a time in the retail hardware business in McPherson, Kan. Later he joined the John Deere Plow Co., at Kansas City, and became sales manager. Leaving that position in 1904, he was occupied from 1905 to 1908 with farm machinery design and construction work for a company that is no longer in business. He entered the automobile business in 1911 as Chicago branch manager for the Buick Motor Co. and after four years became assistant manager and sales manager of the Oakland company. Two years later he was elected president and general manager of that company, and in April, 1917, was elected an Associate Member of the Society. He retired from active business in 1925 and had made his home in Florida for the last five years.

George R. Rowland

A LUBRICATION engineer of authority, who had been associated with The Texas Co., of New York City, since 1910 and a member of the Society since 1918, George R. Rowland passed away at his home in Elizabeth, N. J., on Feb. 11.

Born at Hampton, N. J., in 1867, Mr. Rowland entered the employment of the Central Railroad of New Jersey, at Hampton, in 1883 as an apprentice in the shops, and remained with the railroad until 1910, serving for 10 years as a locomotive engineer. In the latter year he became lubrication engineer for The Texas Co. and the following year was made chief engineer and five years later was appointed supervising engineer, a position which he held until his death.

Besides his membership in the Society, Mr. Rowland was a member of the American Society of Mechanical Engineers and was the author of a treatise on Lubrication and Lubricants that was highly regarded by the oil industry.

William L. McLellan

WORD has been received that William L. McLellan, an Associate Member of the Society, passed away at a hospital in Edmonton, Alta., Canada, on Dec. 5 following a major operation.

Mr. McLellan had been a resident of Edmonton for 25 years, was service manager of McLellan, Ltd., distributors of Willys and Willys-Knight cars, and president of the Edmonton Auto Service Club, which was formed last spring and which the members hope will eventually become a part of a Section of the Society. He was a young man of progressive ideas, an indefatigable worker and will be greatly missed in Edmonton automotive circles.

Born at Dundas, Ont., Canada, in March, 1899, where he attended the public schools, Mr. McLellan became a machinist apprentice at the Edmonton Iron Works in 1916 and attended the Edmonton Technical School at night. From 1919 to 1921 he was a junior machinist in the Nichols Bros. Machine Shop, and then joined the firm of Glyde & McLellan, Ltd., for which he supervised all engine and machine work. In 1923 he was made assistant service manager, and in 1925 was advanced to the position of manager of the service department. In this last position he had charge of the machine and repair shop, the new-car and used-car departments and of correspondence in connection therewith.

Hilton G. Freeland

A MEMBER of the Society for the last 12 years, Hilton G. Freeland, sales metallurgist for the Associated Alloy Steel Co., of Cleveland, passed away recently.

Born at London, Ont., Canada, in 1884, he was graduated in chemistry by the International Correspondence School in 1910 and completed a course in mechanical engineering in 1920, in which year he became a naturalized American citizen. Besides being a member of the S.A.E., he was an Active member of the American Society of Steel Treaters and the Detroit Society of Chemists. He did considerable research work on brass and bronze, with particular reference to bearing-ball production, and also worked up data on redeeming waste oil contaminated with heavy abrasives and iron particles. From 1909 to 1917 he successively served as chemist of the United States Steel Corp., at Gary, Ind.; the Detroit Testing Laboratory; the Michigan Malleable Iron Co., of Detroit; and the General Motors Corp., of Detroit, for all of which he was engaged in analytical work on various metals.

Mr. Freeland joined the Hoover Steel Ball Co., of Ann Arbor, Mich., in 1917 as chemist and assistant metallurgist and had complete charge of analytical work and control of heat-treatment of the product. In 1920 he was made metallurgist of the company. In 1927 he joined the Federal Bearings Co., of Poughkeepsie, N. Y., as metallurgist.

Notes and Reviews

AIRCRAFT

Applied Wing Theory. By Elliott G. Reid. Published by McGraw-Hill Book Co., Inc., New York City and London, 1932; 231 pp. [A-1]

This presentation of phases of aerodynamic theory which are of fundamental importance in airplane design has been prepared primarily for university students of aeronautic engineering and for airplane designers.

The author points out that, since the usual graduate of an American technical school is not very familiar with fluid mechanics and does not have a working knowledge of potential theory or facility in the use of either the complex variable or Fourier series, the existing texts on wing theory are too advanced, too academic or too condensed for maximum usefulness in the classroom or in the engineer's office. These considerations have guided the author in the preparation of this volume.

The theory is that of Lanchester, Kutta, Joukowski, Prandtl, Munk, Glauert and others, collected, brought up to date and coordinated.

Tests of N.A.C.A. Airfoils in the Variable-Density Wind-Tunnel, Series 24. By Eastman N. Jacobs and Kenneth E. Ward. Technical Note No. 404. Published by the National Advisory Committee for Aeronautics, City of Washington, January, 1932; 19 pp., 14 figs. [A-1]

This note is the fifth of a series covering an investigation of a number of related airfoils. It presents the results obtained from tests of a group of six low-cambered airfoils in the variable-density wind-tunnel. The mean camber lines are identical for the six airfoils and are of such a form that the maximum mean camber is 2 per cent of the chord and is at a position 0.4 of the chord behind the leading edge. The airfoils differ only in thickness. The results have been presented in the form of both infinite and finite aspect-ratio characteristics.

Stresses Produced in Airplane Wings by Gusts. By Hans Georg Küssner. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Vol. 22, Nos. 19 and 20, Oct. 14 and 28, 1931; verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 654; 38 pp., 46 figs. [A-1]

Experiments with Intubed Propellers. By L. Stipa. Translated from *L'Aerotecnica*, August, 1931. Technical Memorandum No. 655; 11 pp., 25 figs. [A-1]

The foregoing two Technical Memoranda were issued during January, 1932, by the National Advisory Committee for Aeronautics, City of Washington.

These items, which are prepared by the Research Department, give brief descriptions of technical books and articles on automotive subjects. As a rule, no attempt is made to give an exhaustive review, the purpose being to indicate what of special interest to the automotive industry has been published.

The letters and numbers in brackets following the titles classify the articles into the following divisions and subdivisions: *Divisions*—A, Aircraft; B, Body; C, Chassis Parts; D, Education; E, Engines; F, Highways; G, Material; H. Miscellaneous; I, Motorboat; J, Motorcoach; K, Motor-Truck; L, Passenger Car; M, Tractor. *Subdivisions*—1, Design and Research; 2, Maintenance and Service; 3, Miscellaneous; 4, Operation; 5, Production; 6, Sales.

The Buckling of a Cylindrical Shell under Torsion. By Katsutada Sezawa and Kei Kubo. Report No. 76 of the Aeronautical Research Institute, Tokyo Imperial University, December, 1931; 63 pp., illustrated. [A-1]

Although the problem of the buckling of a cylindrical shell that is subjected to shearing forces acting circumferentially at its ends is important in connection with the torsion to which the light metal fuselage of an aeroplane is subjected during flight, the theoretical side of the problem does not seem to have received much attention, probably because of the difficulty of obtaining its mathematical solution.

The object of this investigation was to study, both mathematically and experimentally, the problem of the buckling of a cylindrical shell that is clamped or supported at its two ends and subjected to a uniform shearing force.

Special apparatus was designed for the experiments. The cylindrical shell to be twisted consisted of india-rubber sheeting, varying in thickness from 0.6 to 2.8 mm. and stretched over two metal discs, one forming the top and the other the bottom end of the shell. A steel shaft ran through the center of these discs, the upper disc being fixed while the lower disc was free to slide up and down the shaft, the range of motion being from 50 to 350 mm. (1.97 to 13.78 in.). The diameter of the discs, and therefore of the cylinder, is 100 mm. (3.937 in.).

Only such force was applied that the stresses in the rubber approximately satisfied the linearity of the stress-strain relation and that the rubber was free from hysteresis. In general, the experiments gave results tending to agree with those required by mathematical theory.

The Influence of Atmospheric Humidity and Other Factors upon the Static Lift of Airships. By W. G. Bird. Published in *The Journal of the Royal Aeronautical Society*, November, 1931; p. 973. [A-1]

The author points out that almost invariably, upon completion of an airship, a considerable deficiency is revealed between the designed lift and the apparent value deduced; for example, from a "lift and trim" trial. The deficiency may result from a variety of causes, but small but accumulative errors may possibly exist in present lift formulas, because of the use in their establishment of assumptions that are only approximately true and of the lack of exactness in certain fundamental definitions.

The author therefore examines carefully the theory of such formulas, to check numerically the error involved in any hypothesis, with a view toward deducing accurate equations in a form suitable for computation by logarithms or slide-rule.

Requirements of Airplane Coatings. By J. L. McCloud. Published in *Industrial and Engineering Chemistry*, December, 1931, p. 1334. [A-1]

The author points out that the greater portion of present-day airplane structures is of light metal alloys which are prone to corrosion of the intercrystalline type. Such corrosion lowers the elongation obtained in tensile-test specimens and creates what is called a more brittle condition. The best way to evaluate protective coatings, he contends, is to apply them to test bars of thin, light metals and steels. These coated test pieces are exposed to corroding conditions, and the changes in physical properties are measured and plotted. Comparisons of the results obtained from long-time salt-spray corrosion tests and exposures to roof conditions in Florida are given.

Die Entwicklung Schneller Post- und Personen-Flugseuge für den Deutschen Luftverkehr. By Erich Schatzki. Published in *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Jan. 14, 1932, p. 1. [A-1]

Commercial aircraft speeds have not increased in Germany in the same proportion as have possible aircraft speeds as indicated by world records. The newest transport and mail craft are said to be capable of only 30 per cent faster travel than were their predecessors of 10 years ago, while racing models have been forced to speeds almost double those of the 1920 records.

Up to this time a justification for the comparative slowness of German

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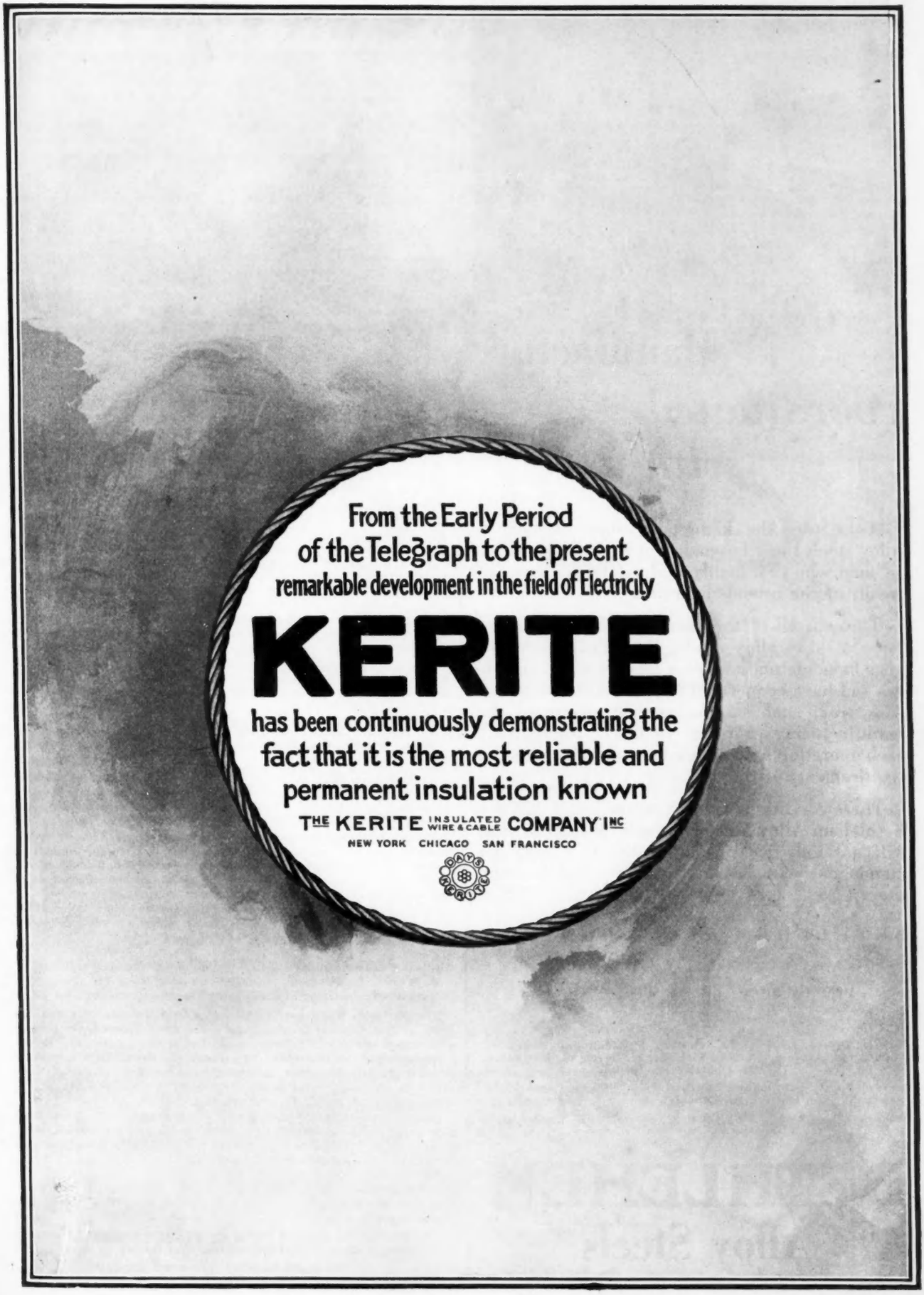
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remarkable development in the field of Electricity
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Notes and Reviews

Continued

commercial airplanes might be found in the high cost of speed. With the present high state of the aerodynamic and powerplant art, such justification no longer exists, asserts the author, who urges that mail and passenger air transport be speeded up. He points out the increased field of utilization that would result from such a move, and the conditions of traffic available and aircraft and engine design that must be maintained to assure success.

Current commercial models used in the United States are presented as examples on which to base the new design types, and their performance curves are compared with those of German airplanes. One interesting observation on airplane design is that the space allotted per passenger in present types of airplane is much greater than in automobiles and might well be reduced in the interest of economy.

Jahrbuch der Luftfahrt: Vol. 1, Militär-Luftfahrt; Vol. II, Handels-und Verkehrs-Luftfahrt; Vol. III, Sport-Luftfahrt. Edited by Dr. Ing. Werner v. Langsdorff. Published by J. F. Lehmanns Verlag, Munich, Germany, 1931; 581 pp.; 717 ill. **[A-1]**

This aircraft yearbook, edited by Dr. Ing. Werner v. Langsdorff, is meant to appeal, not only to the aircraft engineer, but also to the wider circle of those who are non-technically interested in aviation. It is divided into three sections: military, commercial and transport, and sport aircraft.

A large part of each volume is devoted to the design of aircraft in the field covered; however, no attempt is made at comprehensive descriptions, only details thought to be peculiar or significant being dwelt upon. Each volume contains in addition a number of articles on aircraft operation. Authors of such contributions include officials of the Luft Hansa, the Nordbayer. Verkehrsflug A. G., and other prominent figures in German civil and military aeronautics.

The contributed articles in the volume on military aircraft cover the equipment of the military air forces in various countries, lighter-than-air craft, captive balloons, aircraft weapons, parachutes, ambulance airplanes and shipboard launching. Aspects of commercial aviation reported on include German long and short-distance transport; international transport; night flying; lighter-than-air craft; reliability, economy and relation between speed and economy in air transport; and aerial photography and surveying. The volume on aviation as a sport deals with the international aspects, training airplanes, lighter-than-air craft, engine developments, instrument panels, the costs involved and refueling in the air.

Zur Berechnung auf Knickbiegung Beanspruchter Flugzeugholme. By Alfred Teichmann. Published in *Luftfahrtforschung*, Dec. 30, 1931, p. 85. **[A-1]**

This mathematical analysis of the bending strains in stressed wing spars is intended to amplify the methods currently used in wing-spar calculations. Such calculations are said to be made customarily without consideration of the interplay between the spars occasioned through the ribs. Further, the effect of variations in rigidity over the spar length are said to be taken into account only through rough approximations. Finally, spars extending over more than one bearing point are considered as if these bearing points were in one line.

In this article the author develops a method that takes these factors into full consideration so that a check on the customary calculations is possible.

Airplane Construction and Repair. By John E. Younger and Nairne F. Ward. Published by the McGraw-Hill Book Co., Inc., New York City and London, 1931; 433 pp., illustrated. **[A-2]**

The Federal Board for Vocational Education has specified the work of the airplane mechanic to cover all the necessary service and repair work on airplanes, exclusive of the engine, engine instruments and the propeller. At present, the work of the mechanic is said to be somewhat specialized under five principal subdivisions; namely, wire work, fabric work, wood work, metal work (including welding), and rigging.

A job analysis of the mechanic's trade was compiled and this text prepared in an effort to supply fundamental material, augmented by problems and experiments for practical applications and for study of the fundamental concepts.

Aviation Handbook. By Edward P. Warner and S. Paul Johnston. Published by the McGraw-Hill Book Co., Inc., New York City and London, 1931; 715 pp. **[A-3]**

The authors make clear that their intention was not to present a textbook in aeronautical engineering, but simply to make avail-

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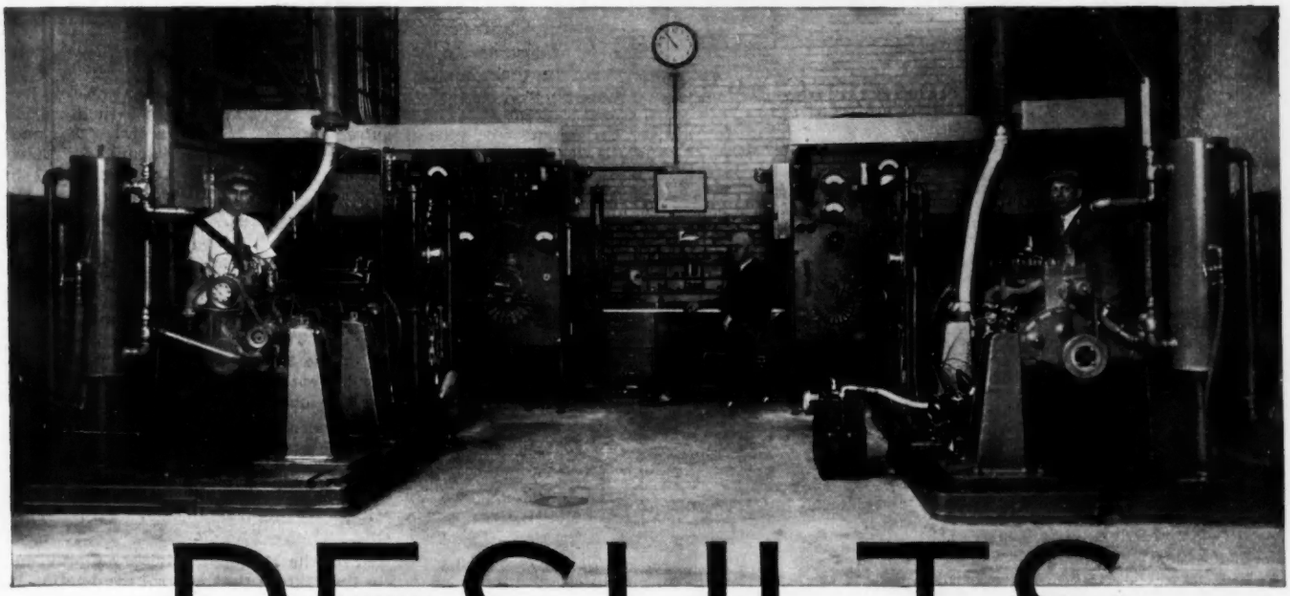
There is no substitute for



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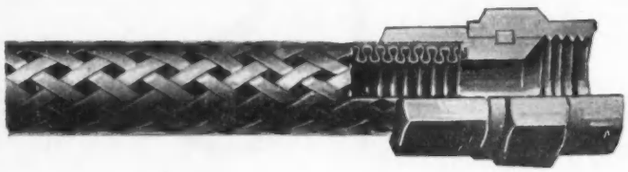

For sixteen years used and specified as original equipment by automotive engineers for gas and oil fuel lines in place of solid tubing for automobiles, trucks, tractors, buses, aeroplanes and motor boats

Titeflex Metal Hose Co.

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Notes and Reviews

Continued

able to designers and engineers basic facts and formulas to assist them in their work. No attempt was made to enter the field of lighter-than-air craft. The work is a compilation of data drawn from many sources, condensed and arranged in a manner consistent with the requirements of the designer. The main classifications in this handbook are: Nomenclature for Aeronautics, Aerodynamics, Parasite Drag, Airplane-Performance Data, Stability and Control, Airplane Materials, Structural Data, Airplane Weight Analysis, Data on Airplane Equipment, and Design Standards.

U. S. Aerodrome Lighting. By K. W. Mackall. Published in *Aircraft Engineering*, November, 1931, p. 285. **[A-4]**

This report on American practice, giving details and characteristics of the various types of airdrome lights in current use, was presented at a meeting of the International Illumination Congress in Edinburgh, Scotland, Sept. 7, 1931, by the chairman of the United States Subcommittee on Airport Lighting.

ENGINES

Combustion in a High-Speed Compression-Ignition Engine. By A. M. Rothrock. Report No. 401. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 17 pp., illustrated. Price, 15 cents. **[E-1]**

An investigation conducted by the National Advisory Committee for Aeronautics to ascertain the factors that control combustion in a high-speed compression-ignition engine is presented. Indicator cards were taken with the Farnboro indicator and analyzed according to the tangent method devised by Schweitzer. The analysis shows that, in a quiescent combustion chamber, increasing the time lag of auto-ignition increases the combustion efficiency of the engine and also the maximum rate of combustion. Increasing the maximum rate of combustion increases the tendency for detonation to occur. The results show that, by increasing the air temperature during injection, combustion can be forced to start during injection and thereby prevent detonation. The author shows that the rate of fuel injection does not, of itself, control the rate of combustion.

Effect of Orifice Length-Diameter Ratio on Fuel Sprays for Compression-Ignition Engines. By A. G. Gelalles. Report No. 402. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 14 pp., illustrated. Price, 15 cents. **[E-1]**

Experimental results on the effect of the length-diameter ratio of the orifice on the spray characteristics, together with a brief analysis of the factors affecting these characteristics, are presented in this report. The length-diameter ratios tested ranged from 0.5 to 10:1; the orifice diameters from 0.008 to 0.040 in.; and the injection pressures from 2000 to 8000 lb. per. sq. in. The density of the air into which the fuel was discharged was varied from 0.38 to 1.35 lb. per cu. ft.

When a plain stem was used in the injection valve and the length-diameter ratio of the orifice was increased from 0.5 to 10:1, the rate of spray-tip penetration at first decreased and reached a minimum between the ratios of 1.5 and 2.5; then it reached a maximum between the ratios of 4 and 6; and next decreased as the ratio was increased to 10:1. The exact position of the maximum and minumum points depended upon the orifice diameter. The spray-cone angle was affected very little by variation of either the diameter of the orifice or the length-diameter ratio tested at ratios greater than 4:1.

With a helically grooved stem in the injection valve, the ratios at which the highest penetration occurred varied between 5 and 7:1. The spray-cone angle increased with the ratio of orifice area to groove area.

The Effect of Increased Carbureter Pressure on Engine Performance at Several Compression Ratios. By Oscar W. Schey and Vern G. Rollin. Report No. 404. Published by the National Advisory Committee for Aeronautics, City of Washington, 1931; 12 pp., illustrated. Price, 10 cents. **[E-1]**

The object of the investigation herein reported was to ascertain the effect of increasing the carbureter pressures from 30 to 40 in. of mercury, at compression ratios from 3.5 to 7.5:1, on the power, on the maximum cylinder pressures, on the fuel consumption, and on the other performance characteristics of an engine. The tests were conducted on the N.A.C.A. single-cylinder universal test engine by the staff of the National Advisory Committee for Aeronautics. A Roots-type aircraft-engine supercharger was used to maintain the desired carbureter pressure.

(Continued on next left-hand page)

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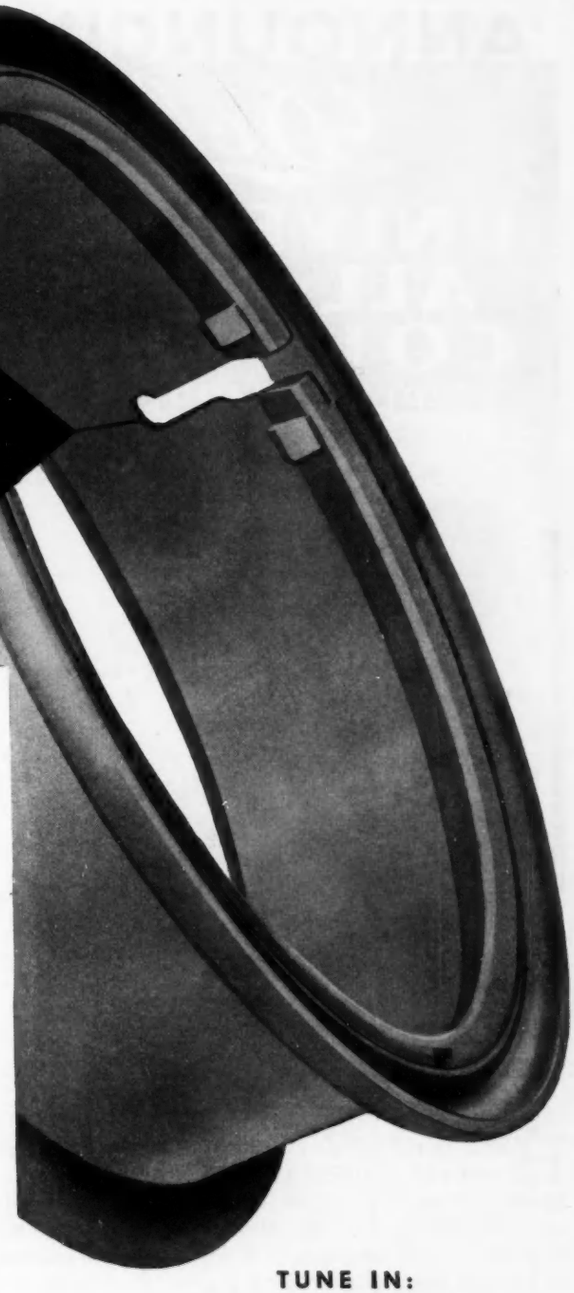

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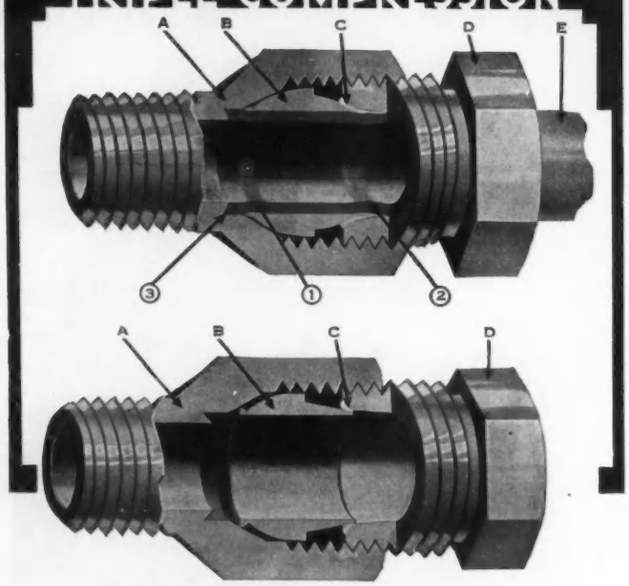

WITHOUT TUBING – BEFORE COMPRESSION

(1) First Compression
(2) Second Compression
(3) Third Compression
Patented February 3, 1931
No. 1,791,121

(A) Body
(B) Sleeve
(C) Solder Bearing
(D) Nut
(E) Seamed Tubing

Approved by the Underwriters Laboratories

HERE is the result of supreme engineering effort and experience to provide a single type of compression coupling to fit universally all seamed or seamless tubing of steel, aluminum, brass or copper. It is no longer necessary to depend upon couplings of various designs and construction for joining differently constructed kinds of tubing.

This Dole Universal All-Tube Coupling of two piece design surpasses all for joining to seamed or seamless tubing—for safety against leakage—for holding under all strain and vibration—for simplicity of connection—no separate sleeves—no flaring—no soldering—for reconnecting speedily and without limit—*for ultimate satisfaction and economy.*

The coupling consists of only the body and the threaded sleeve screw. Repeated connecting will not reduce the efficiency. Finger turned except for the compression turn. The solder which holds the sleeve on to the nut is sheared off during compression, thus giving a lead lubricated bearing—an exclusive Dole feature.

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Notes and Reviews

Continued

Results of these tests show that (*a*) the decrease in brake thermal efficiency with boosting is negligible; (*b*) the power increases with boosting much more than the losses to the cooling water increase; (*c*) a large increase in power can be obtained with comparatively small increase in maximum cylinder pressures; and (*d*) it is advisable to supercharge an engine of highest practicable compression ratio consistent with the degree of supercharging desired and the nondetonating quality of the fuel used, because the power increase will be greater, the exhaust gas temperatures will be lower, and the power required by the supercharger to maintain the same pressure at the carbureter will be less.

Liquid Cooling of Aircraft Engines. By Hanns Weidinger. Translated from *Zeitschrift für Flugtechnik und Motorluftschiffahrt*, Vol. 22, No. 18, Sept. 28, 1931; verlag von R. Oldenbourg, München und Berlin. Technical Memorandum No. 649; 11 pp., 15 figs. **[E-1]**

This translation was issued during December, 1931, by the National Advisory Committee for Aeronautics, City of Washington.

The Turbo-Compressor and the Supercharging of Aero Engines. By F. O. F. Whittle. Published in *The Journal of the Royal Aeronautical Society*, November, 1931, p. 1047. **[E-1]**

The author develops in considerable detail some of the theory and problems peculiar to supercharging by means of the turbo compressor. The subject is discussed only as it concerns the engine.

The general theory of the turbo compressor is given briefly, and the lines of development which compressor design should follow and the possible development of supercharger control are indicated.

According to the author, next to the exhaust turbine-driven type, an auxiliary engine for the supercharger apparently would be the most satisfactory method of drive and control, provided the practical difficulties are not too great.

Another method, better than the single gear ratio, is a two or three-speed gear and gear-changing mechanism.

The adiabatic efficiency of the compressor has a pronounced effect on the permissible degree of supercharging with uncooled types, and on the extent of intercooling necessary with types to which intercoolers are fitted.

The brake thermal efficiency of the unsupercharged engine at heights is increased by supercharging without intercooling, and may be either increased or decreased by intercooling, according to the extent of supercharging and intercooling employed. The improvement in efficiency results mainly from the beneficial effect of the higher mean effective pressure on the mechanical efficiency and partly from the regain, during the induction process, of power expended in supercharging.

The restriction to a maximum boost pressure used on supercharged engines of modern types is unsatisfactory and should be replaced by restrictions on the revolutions per minute and the induction density; the external atmospheric temperature also should be taken into consideration.

Finally, the writer believes it to be well within the bounds of possibility to fit commercial aircraft with single-stage superchargers to enable them to fly economically over long distances at altitudes of the order of 38,000 ft., provided some serious effort is made to improve the efficiency of the supercharger and the method of control.

Les Véhicules Industriels à Moteur Diesel au XXV^e Salon de l'Automobile. By G. Delanghe. Published in *Le Génie Civil*, Jan. 16, p. 65, and Jan. 23, 1932, p. 90. **[E-1]**

The Diesel-powered commercial vehicles in the 25th Paris automobile salon were of distinct interest. Extensive descriptions of the engines are given in this article, particularly detailed attention being given to the fuel-injection systems. Included are discussions of the Renault, Panhard, Berliet, Sauer and Tatra automotive Diesels and the R.E.F. and Bellem fuel-pumps and injectors.

L'Evolution de la Technique des Moteurs d'Aviation; les Améliorations de Detail. By G. Ivanow. Published in *La Technique Automobile et Aérienne*, 4th Quarter, 1931, p. 102. **[E-1]**

While the study of fundamentals is necessary to effect improvements in aircraft engines, the perfection of details as a concrete realization of such study is no less essential to progress, declares the author. With this thought, he has here assembled examples believed to be characteristic of the several designs and indicative of the trend of development.

(*Continued on next left-hand page*)

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But you can provide good riding comfort for every kind of road, with Delco Ride-Regulating Control. Plan now for the installation of these dash-controlled shock absorbers in your next car models. An experienced Delco-Lovejoy engineer will help you in planning your complete layout.

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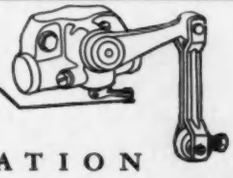

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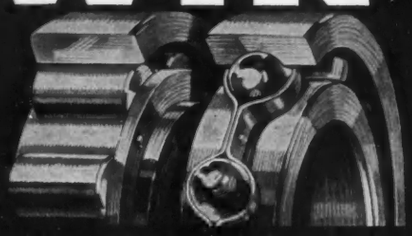
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IN the past twenty years many standards have become flexible, and quality has become a variable thing . . . But, throughout this period NORMA-HOFFMANN Precision Bearings have continued to be the choice of those who measure value by service rendered, and who seek the lowest cost per bearing per year of useful bearing life.

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Notes and Reviews

Continued

Among the design features described are the Napier roller-bearing crankshaft, the Hispaño-Suiza air-cooled crankshaft bearings, the demountable Hirth crankshaft, the needle form of roller bearing as used in connecting-rods, aluminum and magnesium-alloy pistons, magnesium-alloy crankcases, valve-actuating mechanisms, turbine and gear-driven superchargers, together with their effect on engine and aircraft performance, and the Leparmantier automatical variable-pitch propeller.

Die Kräfte an der Kurbelwelle. By Karl Herr. Published in *Automobiltechnische Zeitschrift*, Oct. 10, p. 604; Oct. 31, p. 688; Nov. 30, p. 761; Dec. 15, p. 791, and Dec. 31, 1931, p. 814. **[E-1]**

By working through an example, a method for the graphic determination of the magnitude and direction of crankshaft forces is herein demonstrated. It is claimed to be comprehensive, accurate and, after practice, easy to use.

The method is based upon the assumption that, in crankshaft design, three requirements to be regarded as essential are (*a*) bearing durability, (*b*) dynamic balance of the crankshaft and (*c*) torsional rigidity. To fulfill these requirements the designer must know connecting-rod-bearing and the main-bearing pressures, how to achieve dynamic balance through counterweights, the vibration period of the crankshaft and its torsional characteristics. The graphic method worked out is presented as a means for obtaining information on these points.

Diesel Questions and Answers. By Julius Rosbloom. Published by the Industrial Institute, Jersey City, N. J., 1932; 173 pp. **[E-3]**

This book covers principles in Types and Design of Diesel Engines, Engine Operation, Auxiliaries, Marine Practice, Fuel and Lubricating Oils, Accessories, and Figuration. It is intended to assist engineers and students in clarifying subjects encountered in Diesel practice.

MATERIAL

The Dilution Theory of Detonation. By I. A. J. Duff. Published in *The Journal of the Institution of Petroleum Technologists*, December, 1931, p. 697. **[G-1]**

The author offers evidence that the cause of "pinking" is an interaction of a small quantity of the fuel and oxygen of the charge, as previously described by Callendar, Mardles and King, and that the increase of knocking tendency varies directly with the concentration of oxygen in the charge. As no equally simple law applies to all classes of antiknock fuels, the assumption is made that a small portion of the oxygen content of the charge is reactive but only during the latter part of the compression stroke and first portion of the firing period, and that this combines with any of the pro-knock fuel with which its active molecules come into contact.

The phenomenon of delayed action in the ignition of charges adiabatically compressed above a certain point is explained and employed as follows:

It is thought that above a certain limiting temperature the products preferred to act in some way as "irritants," causing more or less rapid temperature rise until a point is reached at which ignition begins. Making a few simple assumptions that are justifiable, according to the author, a mathematical expression is developed for several different types of antiknock, connecting the improvement of engine test with the quantity of diluent or antiknock present.

Figures thus derived theoretically are asserted to agree with those determined practically by several different observers, at various times and places and on different engines, with an accuracy equalling or surpassing the experimental error, in the case of fifteen different combinations of knock inducers and knock suppressors.

The Ignition Quality of Fuels in Compression-Ignition Engines. By G. D. Boerlage and J. J. Broeze. Published in *Engineering*, Nov. 13, 1931, p. 603. **[G-1]**

Knowledge regarding the connection between the characteristics of a fuel and its behavior in an engine, more particularly regarding its ignitability and tendency to cause knocking, was felt by the authors to be insufficient, and the ever-increasing use of the small oil engine made the study of this problem more urgent.

A program of both laboratory and engine research was therefore initiated. The investigations in the laboratory research were mainly in two directions: (*a*) chemical and physical, with the objects of determining the reactions occurring during ignition and combustion and of finding the relationship between these reactions

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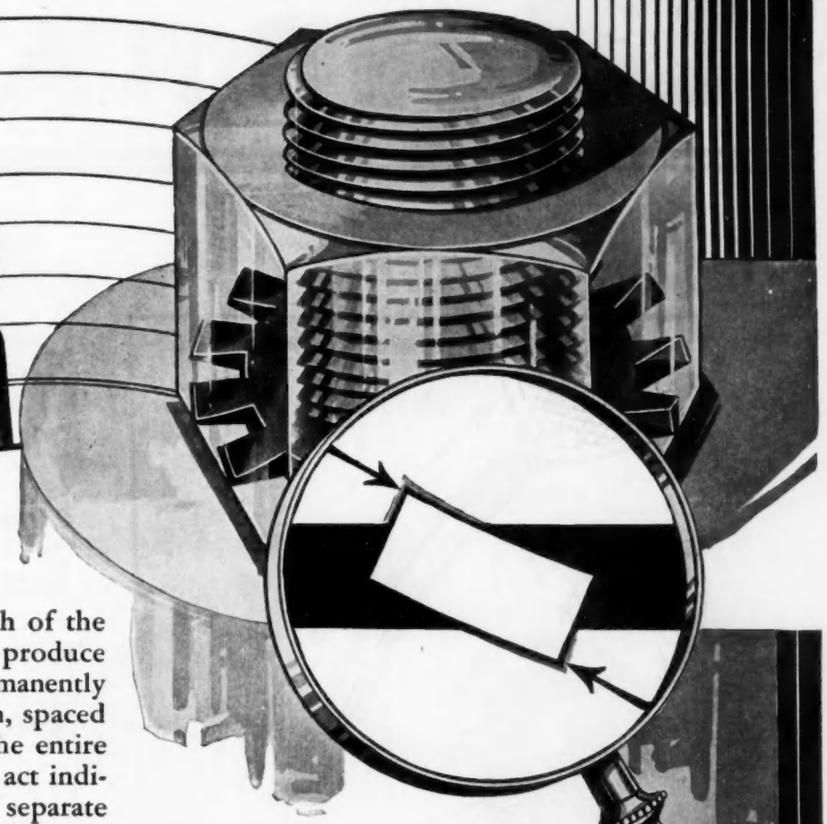
SHAKEPROOF

Multiple Locking Defeats Vibration



THE patented twisted teeth of the Shakeproof Lock Washer produce a locking force that assures permanently tight connections. These teeth, spaced at regular intervals around the entire circumference of the washer, act individually to form a series of separate locks. And what's more—each tooth is a double action lock because it bites into both the nut and the work surface.

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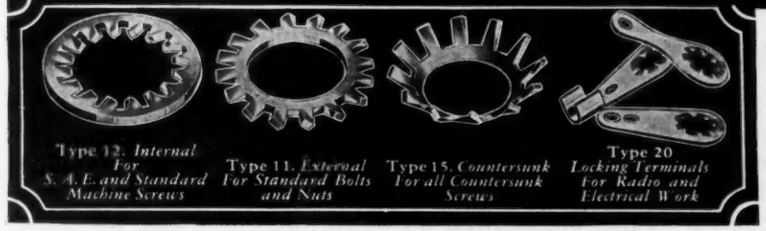

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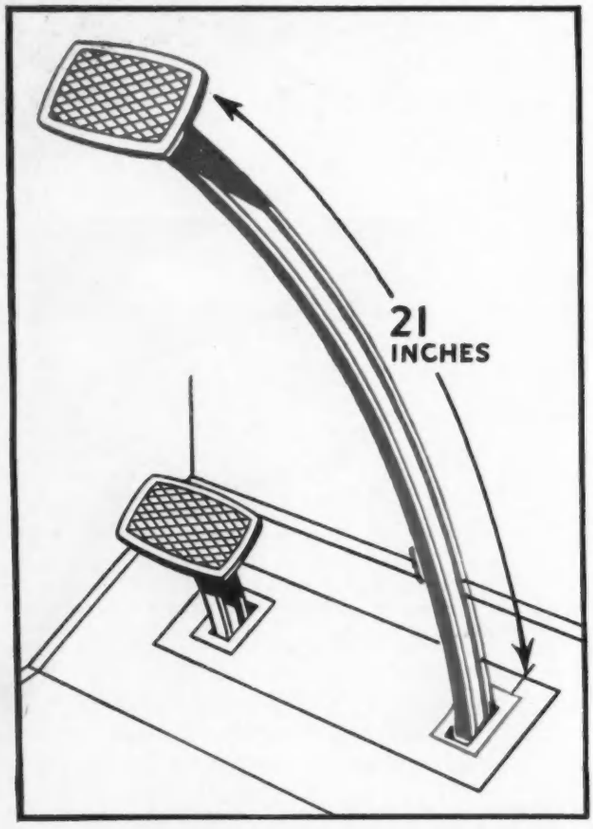
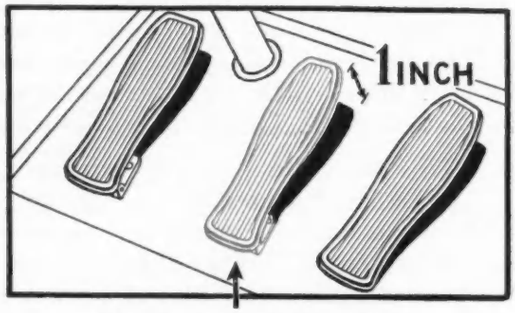
21 TIMES BRAKING



Socking down a GIANT *21-*INCH *brake pedal would barely equal the braking effectiveness gained at 1 inch travel of the* STEWART-WARNER *Brake Pedal . . .*



The Brake Pedal of Today

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10 OUTSTANDING ADVANTAGES OF

1. The power unit, under driver's absolute control, harnesses the giant force of car momentum to apply these brakes.
2. Instant Control—Lower Pedal Pressure and Shorter Pedal travel with accurate response.
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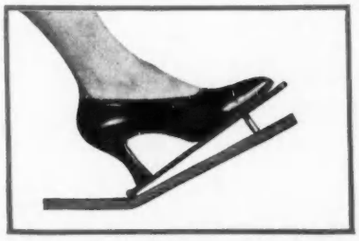
5. Safer Braking—Accurate distribution of braking force to all 4 wheels.

GREATER EFFECTIVENESS

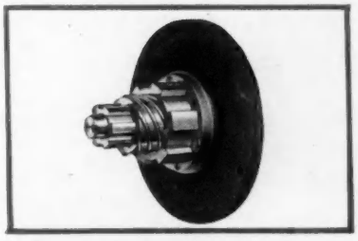
This greater effectiveness of Stewart-Warner Brakes means less driver's fatigue, time saved, accidents avoided. Normal braking at any speed is as easy as operating the foot accelerator . . . . . .

A GENTLE ROCKING MOTION ON THE PEDAL



No lunging leg action required on the Stewart-Warner Brake Pedal—which is no higher than a foot accelerator and for normal braking at all speeds operates just as easily.

GOVERNS THE POWERFUL MECHANICAL FOOT



The Power Unit offers the maximum braking effectiveness in cars of every price class from the lightest to the heaviest automobile, motor coach or truck.

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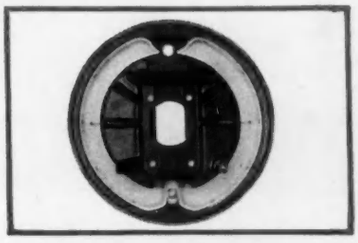


Even without the Power Unit, Stewart-Warner Wheel Brakes, because of rigid construction and a simplicity of design which uses 1/4 the usual number of parts, is much more effective than conventional Pedal Installations.

Quicker adjustment and higher mileage between adjustments, means money saved for car, motor coach or truck operator who uses Stewart-Warner Brakes. Investigate. Our engineers are at your call. Stewart-Warner Corporation, Chicago, U. S. A.

BRAKE SYSTEMS

STEWART-WARNER BRAKE SYSTEMS

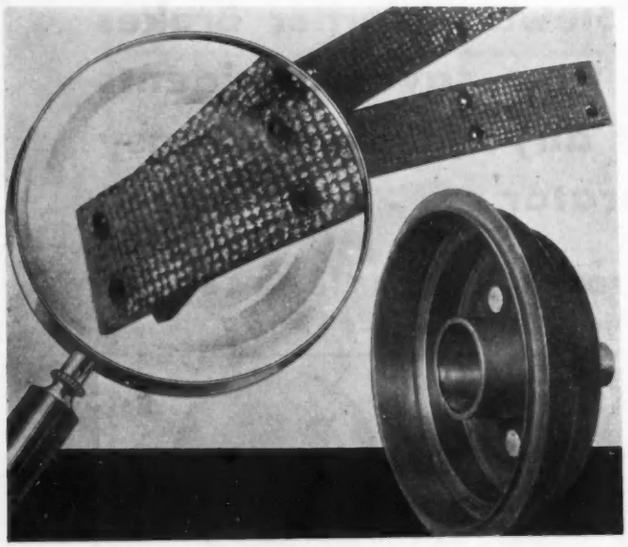
6. Simplest of all brakes to Adjust.
7. Safer Brakes on curves—Positively no interference with steering.
8. Simplest to Install and to Maintain—Only 25% as many parts as in other Brake Systems.
9. 17 parts including brake lining in each front wheel—only 14 parts in rear wheel. Parts interchangeable.
10. Self-adjusting Hand Brake—Has automatic Booster Link take-up.

45 TRIPS

down Ligonier Mountain

with no appreciable wear to lining or drums

● Forty-five times was Rusco Test Car No. ET5 started from the summit of Ligonier Mountain and allowed to free wheel the entire distance to the bottom. Yet, as the accompanying photographs show, there was no sign of the lining burning out, fading, charring or cracking. Nor were the drums (cast iron) scored to the slightest degree.



The procedure followed in this test was as follows: First, the car was loaded with 600 pounds of ballast in addition to the weight of the driver. Second, starting at the summit of the mountain, the car was accelerated to a speed of 40 miles an hour. Third, the car was put in free wheeling and held at 40 m.p.h. by constant application of the brakes. Fourth, upon completion of the 4½-mile run to the bottom and while the car was still traveling at 40 miles an hour or more, an emergency stop was made, severe enough to lock both rear wheels.

In addition to the absence of any signs of wear to lining or drums, the following data is of interest: The pedal pressure required to hold the car at the fixed speed of 40 m.p.h. was 30 lbs. The final stop was made at a deceleration of 15 to 18 ft. per second^2, and with a pedal pressure of 125 pounds.

Complete performance data on Rusco linings for your brake will be furnished gladly upon request. Address, Engineering Department B78, The Russell Manufacturing Company, Middletown, Conn. Incorporated 1834.

RUSCO

MOLDED OR WOVEN

BRAKE LININGS

Notes and Reviews

Continued

and the constitution of the fuel; and (*b*) the more practical direction, which involved an endeavor to obtain an insight into the phenomena governing ignition and combustion by means of laboratory tests more or less representative of engine conditions, such as the heated-pot tests employed for the determination of the lowest temperatures of spontaneous ignition at atmospheric pressure of S. I. T. (Moore) and at high pressure (Tausz and Schulte), the measurement of ignition lag (Hawkes, A. L. Bird, Neumann) and the calculations of Professor Neumann.

It was felt to be necessary to conduct tests under actual engine conditions, since so many unknown variable factors enter in practice, that little likelihood exists of all being taken into account in a simple laboratory test. Moreover, the authors point out that comparison of the behavior of fuels in engines by means of clear and reproducible tests is necessary. What is required is a method of rating ignition quality which will be directly applicable in practice, similar to the determination of the knock rating of fuels in knock-testing engines.

A method for rating ignition quality, developed as a result of these tests, is described, and subsequently a series of correlated results obtained with tests on engines of other types is given.

The article is published in three installments, the second and third appearing in the Dec. 4 and 18 issues of *Engineering*.

Use of Metals at High Temperature. By H. A. DeFries. Paper presented at the conference on metals and alloys, held at the Case School of Applied Science, Cleveland, Nov. 18 to 20, 1931. **[G-1]**

The author points out that for several years past the advances in certain industries have made it necessary to consider the use of metals at higher and higher temperatures. With rising temperatures the properties of metals become quite complicated, and, in addition to the study of load-carrying capacity at elevated temperature, it becomes necessary to give careful consideration to the phenomena involved in the attack of various gases and so forth at high temperatures.

Metals for use at high temperature in internal-combustion engines are treated in the second half of the paper. Particular consideration is given to the steels developed for use in exhaust valves to assure freedom from scaling and corrosion at operating temperatures and sufficient strength and hardness to prevent breakage or distorsion. The limiting temperatures for such steels now on the market are also given.

Some other papers presented at the Conference are: Magnesium Alloys, by L. B. Grant; Nitriding Steels, by H. A. DeFries; Bearing Metals, by Christopher H. Bierbaum; Zinc and Its Alloys, by W. M. Peirce; and Light Alloys in Aircraft, by H. W. Gillett.

MISCELLANEOUS

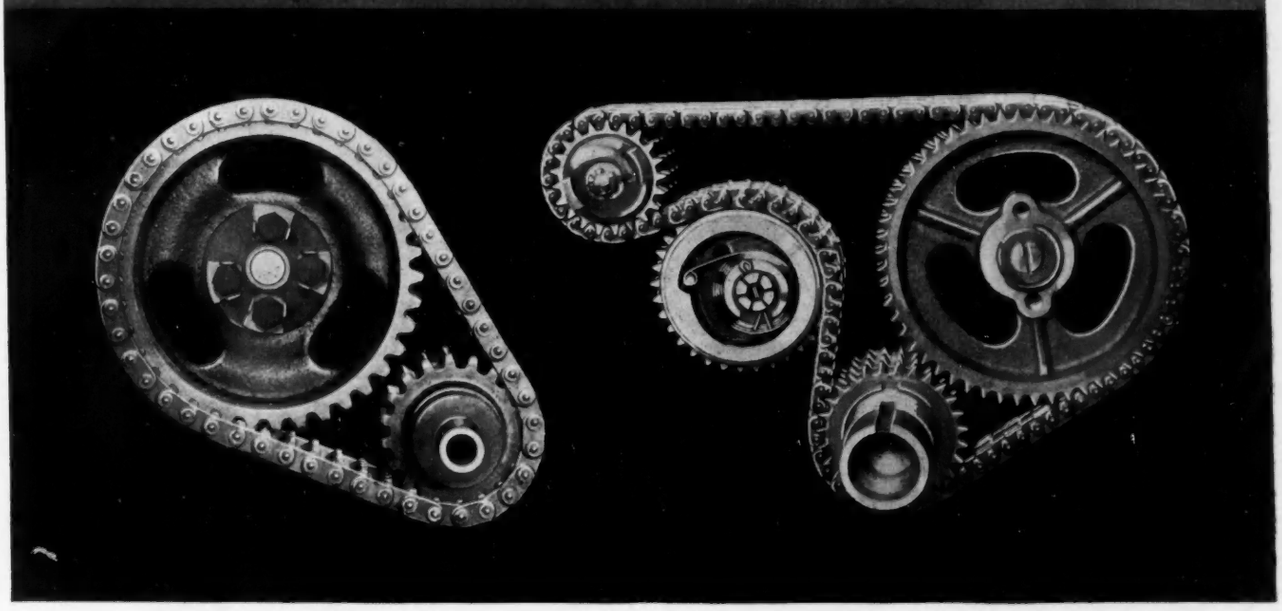
English-French Comprehensive Technical Dictionary of the Automobile and Allied Industries. Compiled by Lewis L. Sell. Published by the International Dictionary Co., New York City; 768 pp. **[H-3]**

Indicative of the increasingly international aspect of the automotive industry are the recent additions to the number of foreign-language dictionaries in this field. The volume of Alfred Schlomann's six-language dictionary dealing with automotive terms, for long practically the only resource of the student or translator, has recently been supplemented by other works. Among these may be mentioned two three-language (German, English and French) dictionaries, one compiled by J. Vanier and published by the American Society of Mechanical Engineers, listing purely aeronautic terms, and the other compiled by Benno R. Dierfeld for the Reichsverband der Automobilindustrie and published by Dr. Ernst Valentin Verlag, including words directly related to the automobile.

The most recent and perhaps most ambitious of these projects tending to build up an international automotive vocabulary is the English-French Dictionary, compiled by Lewis L. Sell and published by the International Dictionary Co. This work embraces, in all their fullness, the automobile and allied industries. Definitions for terms related to chassis, engine, parts, manufacturing, service and operation may be found. Some words of general usage which have particular application in this field, and examples of automotive slang, as for instance, to "negotiate" a hill, are also included. The number of definitions found in this handy and compact volume is, according to the compiler, about 150,000.

(*Concluded on next left-hand page*)

TIMED BY LINK-BELT



The engine that is "timed by Link-Belt"—with Link-Belt Silent Chain—is assured of reliable, quiet-running performance for thousands of miles of running.

For more than twenty-five years—ever since silent chains were first adapted to the automotive engine—Link-Belt Chains have been used by the industry.

Today, Link-Belt stands unequalled! It is a name that means reliability in service, and quality of product.

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AUTOMOTIVE SILENT CHAIN

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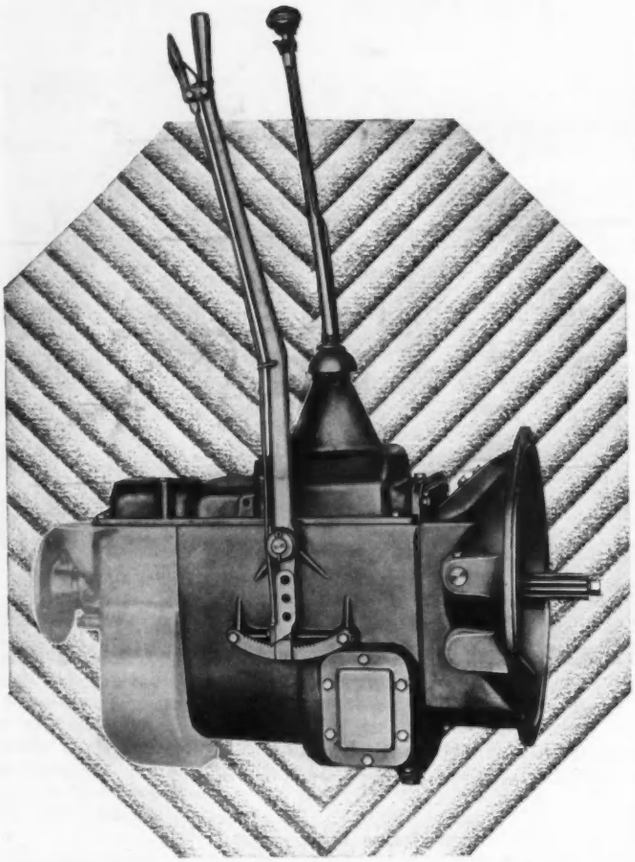
Brown-Lipe 4-5-8-12 Speed Gear Boxes



This new series enables manufacturers to install a four, five, eight or twelve speed assembly by adding the proper over drive or underdrive unit to the basic four speed model. No cab alterations are necessary. Floor boards, clutch pedals and controls remain the same regardless of the assembly used. Suitable ratios for both Trucks and Buses.

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Notes and Reviews

Concluded

As a basis for his work, Dr. Sell has not only studied printed authorities but has consulted experts and manufacturers in this Country and France, so that his compilation represents the living language of the automotive industry.

Listings comprise single words, compound words, phrases and ample cross references. Leading words are accompanied by words or phrases often used with them; for instances, about 200 such references have been made under the word "bearings." Explanations are given where any doubt might exist as to the meaning of the English word, and notation is made where the word is of distinctly English, as contrasted with American, usage. One of the many evidences of the exhaustiveness of the compiler's research is the large number of French terms given for each English word.

Einiges über Konstruktion und Gebrauch von Kraftwagenprüfständen. By H. Kluge. Published in *Automobiltechnische Zeitschrift*, Oct. 20, p. 655; Oct. 31, p. 685; and Nov. 20, 1931, p. 735. [H-1]

An automobile test stand constructed at the Karlsruhe Engineering College in cooperation with the firm of Carl Schenck, in Darmstadt, Germany, is described in this series of articles and directions are given as to the methods of making experimental observations.

Ready means of adjustment are provided so that vehicles of different wheelbases and treads may be accommodated. The test car is attached at only one point on the forward axle so that it has freedom of movement similar to that on the street.

The method by which the engine load is calculated so that it is equivalent to the load carried under normal operating conditions is demonstrated and the friction characteristics of the stand are shown. In discussing the brake requirements, the author states that neither the electric nor the hydraulic brake is suitable for the test stand, and gives his reason for preferring the Prony friction brake.

Methods of making measurements of grade-climbing ability, tractive effort, acceleration, stopping distance and brake adjustment are explained. A more simplified form of test stand is also described.

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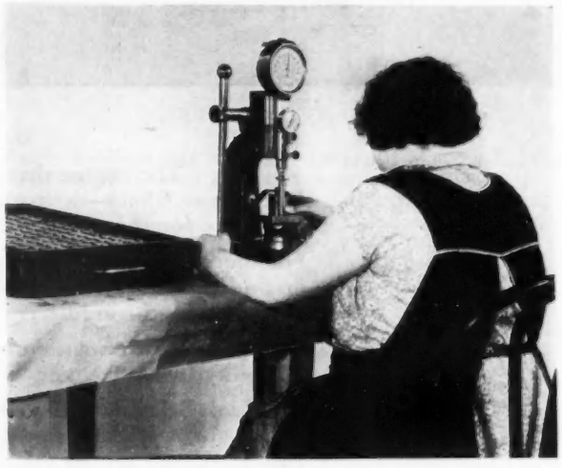
ALONE PAYS in 100% Inspection and Duplicate Manufacturing



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THE MONOTRON is now in wide use on Laboratory and Production work. Non Destructive; Solves sub-surface testing. Speedy, stands up best under continuous hard usage.

THE SCLEROSCOPE. The only Tester that is 100% portable and can be carried to the job. Fast, accurate; exact conversions to Brinell.

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PRICELESS

are the voices of those we love

WHAT PRICE COULD BE SET ON THE VOICE AND LAUGHTER OF A LITTLE CHILD A THOUSAND MILES AWAY? WHAT PRICE ON THE BRIEF AND REASSURING PHRASE, "WE'RE ALL WELL"? WHAT PRICE ON A HUNDRED WORDS BETWEEN SEPARATED LOVERS?

WHAT price on a doctor's midnight directions, on the swift response of the fire department, on the relief of anxiety, the cementing of friendship, the unexpected greeting after a long silence?

What price on speed in business, on the smooth running of a household, on leisure or rest without neglect of duty, on shelter in a day of storm?

How can any one say what the telephone is worth to you? We set a value on such visible, physical things as wires, poles, switchboards, instruments, operation. We set a price on telephone service based on what it costs us to render it and to assure its continued growth. These considerations are fairly exact. But they have little relation to the actual worth of the telephone in your home or office. That is frequently a thing of the spirit and cannot be measured in terms of money.

When you buy telephone service you buy the most nearly limitless service the world affords. Because of it you receive the thoughts and emotions of other people and express your own thoughts and emotions to them. There are no hindering handicaps of time or distance, place or circumstance. For a few pennies a day, you move out of your own little corner in the kingdom of ideas and are free to range where you will.

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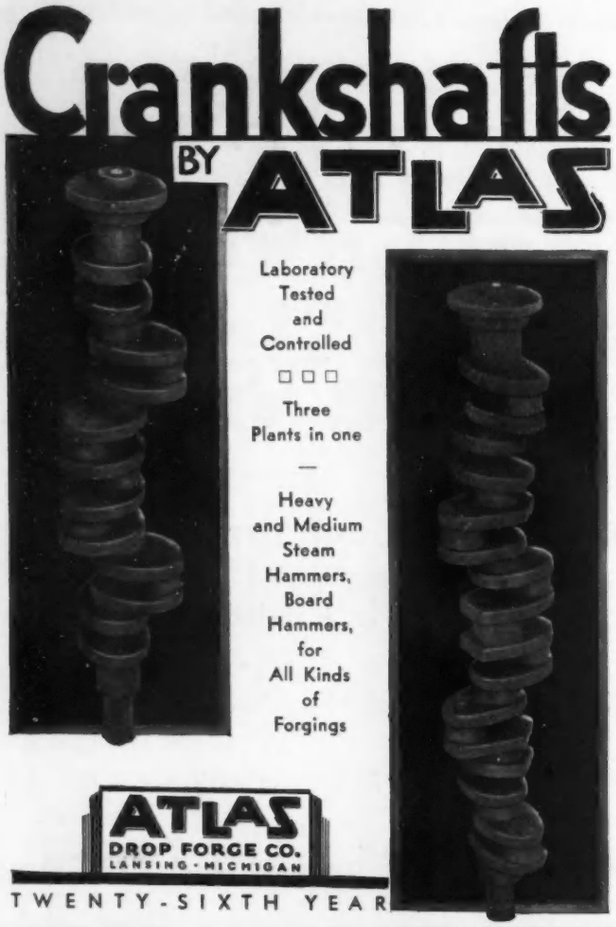

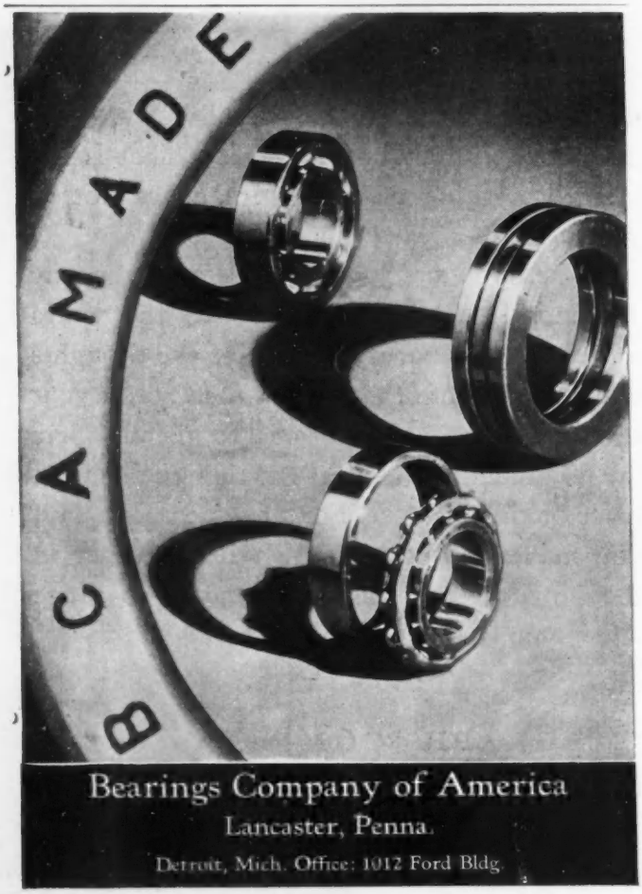

Personal Notes of the Members

(*Concluded from p. 31*)

Juan de la Cierva, inventor of the Autogiro, sailed for England in February after a six-weeks' visit to this Country, during which he was engaged in a series of experiments with the engineers of the Autogiro Co. of America at the company's flight-research field at Willow Grove, Pa., for the further development of the flight principle of the machine. While in America Mr. Cierva was successively entertained by President Hoover, Henry Ford and other National personages.

Merrill T. Clark has relinquished his position as manager of the Portland, Ore., branch of the Laher Auto Spring Co., of Portland, and is going into the life-insurance field.

Harold DeLong Fry, who used to be connected with the Teleregister Corp., of New York City, has been appointed district manager of the Midland Finance Co., at Kansas City, Mo.

F. M. Holden has severed his connection as assistant chief engineer with the Oakland Motor Car Co., of Pontiac, Mich., and has not announced his plans for the future.

Charles B. Jahnke, having left Fairbanks, Morse & Co., for which he was director of engineering, is now connected with the International Harvester Co., of Chicago, as engineer of internal-combustion engines. Mr. Jahnke was reappointed this year a member of the Society's Diesel-Engine Activity Committee and of the Fuels Subcommittee of the Research Committee.

T. S. Johnson, who was fuels engineer of the Vacuum Oil Co. Near East Division, at Cairo, Egypt, has been appointed mechanical engineer in the refined-oil department of the same company.

Walter C. Keys, of Detroit, is now doing consulting engineering work, specializing in chassis and spring suspensions, applications of mechanical rubber, and development and merchandising of patents.

Cyril C. Lawton, having resigned his position as service manager of the Springfield Buick Co., of Springfield, Mass., has assumed the duties of works manager for the White & Bagley Co., of Worcester, Mass., manufacturer of Oilzum products.

Robert B. C. Noorduyn recently became associated with Pitcairn Aircraft, Inc., of Willow Grove, Pa., in the capacity of executive engineer. In 1929 he was vice-president of the Fokker Aircraft Corp. of America and treasurer of the Atlantic Aircraft Corp., at Hasbrouck Heights, N. J., and last year was vice-president of the Bellanca Aircraft Corp., of New Castle, Del.

Edmund B. W. Ormsby has been temporarily transferred from the Naval Aircraft Factory, in Philadelphia, where he was an aeronautic detail draftsman, to the Bureau of Agriculture in the City of Washington. His present position is that of senior agricultural engineering draftsman.

David G. Proudfoot now holds the position of development engineer with the Phillips Petroleum Co., Bartlesville, Okla., and is engaged in the correlation of the refinery output with current demands for automotive and industrial lubrication. Mr. Proudfoot formerly was chief engineer in Detroit for the western region for the Sun Oil Co.

George H. Scragg, formerly an executive of Mack Trucks, Inc., of New York City, is now connected with the Brockway Motor Truck Corp., of the same city.

James D. Redding has entered the employment of the Consolidated Aircraft Corp., of Buffalo, and is engaged in airplane stress analysis.

Carl W. Spohr has given up his position as chief draftsman of the Vacturi Carbureter Co., of Chicago.

Ralph White has relinquished his position as assistant engineer of the Edward G. Budd Mfg. Co., of Philadelphia, and has not announced his plans for the future.

Richard R. Whittingham is now serving the Vacuum Oil Co., at Boston, in the capacity of sales engineer. His previous connection was with the Tourist Garage Co., of Wilmington, Del.